APPLICABILITY OF DIAGNOSIS AND RECOMMENDATION INTEGRATED SYSTEM (DRIS) IN COCONUT PALM (*Cocos nucifera* L.)

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "Applicability of Diagnosis and Recommendation Integrated System (DRIS) in coconut palm (*Cocos nucifera* L.) is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or any other similar title, of any University or Society.

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C E R T I F I C A T E

Certified that this thesis entitled 'Applicability of Diagnosis and Recommendation Integrated System in coconut palm (<u>Cocos nucifera</u> L.)' is a record of research work done independently by Shri. T.I.MATHEWKUTTY under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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CERTIFICATE

We, the undersigned, members of the advisory Committee of Shri. Mathewkutty, T.I., a candidate for the degree of Doctor of Philosophy in Agriculture with major in Agronomy, agree that the thesis entitled "Applicability of Diagnosis and Recommendation Integrated System (DRIS) in coconut palm (*Cocos nucifera* L.)" may be submitted by shri. Mathewkutty, T.I., in partial fulfilment of the requirement for the degree.

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Introduction

1. INTRODUCTION

The coconut palm (Cocos nucifera Linn.) is the most useful palm in the world. Every part of the palm is used for some economic purpose or other and hence it is referred to as the "Tree of Wealth" or the" Tree of Life". It is a most versatile crop providing edible and industrial oil, protein- rich milk and nut water, an invigorating drink. It is also a valuable source of timber, fibre, roofing and matting material and also a number of other products and byproducts from its kernel, shell and other parts.

Coconut is grown in more than 90 countries in the world and India occupies the third position with an area of 1.52 million hectares and a production of 10,043 million nuts (1991-'92). Of this Kerala accounts for 56 per cent of the area and 42 per cent production. The crop makes a significant contribution to the national economy to the extent of Rs 3500 crores with an annual export earning of Rs 97 crores (1992-'93). The present productivity of coconut palm in India is around 33 nuts per palm per year which is much below its potential of more than 100 nuts per palm per year. Lack of adequate and proper management of nutrients is one of the reasons for this low productivity.

The continuous harvesting of nuts and the removal of leaves and all other fallen plant parts with practically no chance for recycling from a perennial crop garden like that of coconut with a life span of 70 to 80 years or more will deplete the soil of one or more elements and makes nutrient management difficult. The strategy for nutrient management in coconut must aim at providing a balanced and optimum supply of nutrients required for high yields. Accurate determination of nutrient requirement for coconut is difficult. Soil analysis could only reveal the soil condition and not the exact need of the palm. Plant analysis provides a useful measure of the elemental status of the palm which can help to improve nutrient management.

Research work conducted in India in diagnosing nutrient deficiencies in coconut palm using plant analysis has been mainly confined to the critical level approach. One of the limitations of this approach in coconut palm is its inability to test clearly the sufficiency and deficiency levels of several major and micronutrients such as P, Ca, Mg, S, Fe, Mn, Zn etc. An objective measure of nutrient balance is also not possible by this technique, though nutrient interactions are known to be important in plant nutrition.

More recently, a method of diagnosing nutrient balance and deficiencies has been proposed by Beaufils (1973). It is a comprehensive system which identifies all the nutritional factors limiting crop production and in so doing increases the chances of obtaining higher crop yields by improving fertilizer recommendations. This method known as diagnosis and recommendation integrated system (DRIS) uses the nutrient ratios in a suitable plant part for diagnosing nutrient imbalances in the plant. Several advantages of this method had been reported in different crops. These include the use of the data in assessing nutrient balance, identification of not only the most limiting element but the order in which the other elements would likely become limiting, the ability to diagnose the plant nutrient needs much earlier in the life of the crop than the critical level method allowing remedial steps to be taken earlier, greater accuracy and relatively more freedom from the effects of some of the sampling variables such as age of the plant part, geographic location etc.

The present study was undertaken to investigate the applicability of diagnosis and recommendation integrated system (DRIS) in coconut palm. The major objectives were to develop DRIS reference norms for major, secondary and micronutrients for diagnosis of nutrient balance and nutrient deficiency in coconut palm and to evaluate the accuracy of the diagnosis by this method.

Review of Literature

2. REVIEW OF LITERATURE

Diagnosis of nutrient deficiencies in coconut palm using plant analysis has been mainly confined to the critical level approach. The use of diagnosis and recommendation integrated system (DRIS) is relatively a new approach to improve the accuracy of deficiency diagnosis and to improve the efficiency of nutrient management for achieving a higher productivity.

In the context of the present study viz. "applicability of diagnosis and recommendation integrated system (DRIS) for coconut palm", the literature on mineral nutrition of coconut palm along with the studies on DRIS on various other crops is reviewed in this section.

2.1. Mineral nutrition of coconut palm

The coconut palm with its massive structure and huge crown and its unique nature of bearing nuts round the year throughout its lifespan of 80 years or more requires a regular supply of nutrients since its establishment in the main field. The perennial nature of the palm as well as its extensive root system pose considerable difficulties in carrying out investigations on its mineral requirements. Various field experiments to study the requirements of major nutrients and to a limited extent of micronutrients on growth and productivity of the palm has been carried out in the major coconut growing countries in the world.

The vital aspect of nutrient management is to ensure the availability of the essential mineral elements in the soil in the required levels and in right proportions for the maximum productivity of the palm. Nathanael (1958) suggested three approaches to the study of the mineral nutrition of coconut viz. assessment of mineral requirements of the palm through fertilizer experiments, analysis of coconut water and leaves, and analysis of the soil for its nutrient supplying capacity. Subsequently Nathanael (1959) has modified the conceptual basis to assess the nutrient requirement of coconut palm by an equation, $F = R-S+L$ wherein F is the quantity of fertilizer nutrient, R is the quantity of nutrient required by the crop for the unrestricted growth, S is the quantity of nutrient supplied by the soil and L is that portion of the nutrient not utilised by the palm. Recent approaches employed for the assessment of nutrient requirements in coconut palm include fertilizer trials, estimation of nutrients removed by the palm, foliar analysis and diagnosis of nutrient deficiencies by visual symptoms.

Foliar analysis and fertilizer recommendations based on established critical levels are more widely adopted. Fertilizer recommendations based on critical levels have limitations. Hence an integrated approach employing different methods based on practical wisdom with respect to each situation is essential for assessing the nutrient requirements of the palm.

2.1.1. N nutrition of the palm

Studies on coconut nutrition have shown that the coconut palm responds well to the application of N. Nitrogen promotes early growth and development of young palms and had a beneficial effect on female flower production.

Murray and Smith (1952) reported that response to N was proportional to the pre-treatment bearing level of the palm. The palms giving an annual yield of 100 nuts and above showed no improvement in productivity due to N fertilization. While reviewing the work done in India upto 1958 on various aspects of fertilizer application to coconut palm Menon and Pandalai (1958) observed that there was general response to the application of N and K while response to P was seen only under specific conditions. Summarising the contributions of IRHO, Paris on mineral nutrition, Fremond (1964) reported that N significantly increased the number of female flowers, number of nuts and copra outturn. Higher doses of N not only depressed the yield of nuts, but also reduced the weight of copra per nut .

According to Smith (1969) N deficiency resulted in reduced female flower production, bunch production, growth rate and yield of palms. Nelliat and Muliyar (1971) obtained response to application of N in terms of yield from the third year onwards and the mean increase in nut production was 16.9 per cent. While reviewing the NPK nutrition of coconut, Nelliat (1973) suggested that the general requirement of N of palms yielding an average of 50 nuts per annum would be 500 g.

Bopaiah and Cecil (1991) reported an yield increase of 123 to 160 per cent in palms receiving 500 g N along with 320 g P2O5 and 1200 g K2O per palm per year in the coral soils of Lakshadweep.

2.1.2. P nutrition of the palm

Phosphorus uptake by the coconut palm is small, nearly one tenth of the total uptake of K as well as Cl. Phosphorus has been found to increase the girth at collar, number of leaves and rate of leaf production in seedlings (Mathew and Ramadasan,1964). Deficiency of this nutrient retards root growth and delays flowering and also the ripening of the nuts.

In an NPK experiment on young palms on red sandy loam soils at Kasaragod, a response to applied P was obtained for two consecutive years. However, the response was not consistent and significant in the succeeding year (Anonymous, 1972). Pillai and Davis (1963) estimated that from a sandy soil of average fertility 12 kg P2O5 were annually removed by 70 palms growing in an acre and yielding 40 nuts per palm per year.

Kamala Devi and Velayudham (1977) found that maximum P concentration was in the 14th leaf (0.17 percent) on the fifth day after fertilizer application. According to Wahid et al. (1977) P and K contents of the leaf were highly correlated. Summarising the contributions of IRHO, Paris to the study of mineral nutrition, Fremond (1964) reported that P was not found to have much beneficial effect either in increasing yield of nuts or copra content. But in the presence of K, P was found to have beneficial effect on the number of nuts and copra yield per nut.

Reviewing the NPK nutrition of coconut, Nelliat (1973) recommended application of 320 g P2O5 per palm per year for palms yielding an average of 50 nuts per annum. He recommended a higher dose of 500 g P2O5 for palms with high yield potential.

Khan et al. (1983) indicated that P fertilizer application can profitably be skipped for at least six years in situations where available soil P is around 20-25 ppm in 30-60 cm depth in coconut basins. Further in 1990, Khan reported that P application to adult coconut palms could be skipped for 14 years when the soil available P was around 40 ppm at 0-90 cm depth.

Though P is a very important nutrient for coconut, it appears that it is normally not a limiting nutrient for coconut production. More so, adult palms have not been found to be much benefited by annual P applications. Fertilizer experiments have shown that the P needs are low, response slow and inconsistent.

2.1.3. K nutrition of coconut palm

Coconut tree is a heavy consumer of potash. Studies conducted in the coconut growing countries of the world have shown that K is a dominant nutrient of the palm and substantial increases in yield have been obtained by its application. The response to potash is usually reflected in the high setting percentage and better copra outturn.

According to Salgado (1953), K deficiency leads to chlorosis, leaf scorching and the development of poor crown with short fronds. Smith (1969) reported that K deficiency reduced the fruit setting and yield while it had not influenced the nut size.

Reviewing the NPK nutrition of coconut, Nelliat (1973) suggested that the general requirement for palms yielding 50 nuts per annum is 1200 g K2O per palm per year while palms with high yield potential requires a higher dose of 2000 g K2O per palm per year. Wahid *et al*. (1974) while studying the relationship among root CEC, yield and mono and divalent cations in coconut reported a positive correlation of both soil and leaf K contents with yield indicating the role of K in increasing the yield of coconut.

Manicot *et al*. (1979 a) has opined that K deficiency in coconut has been noted on tertiary and quaternary sands of West Africa, on coast lands of Sambava, on coral soils of the Oceanian atolls, on sandy soils of east west of Sri Lanka and on the exhausted lateritic zones of west coast of India.

Singh and Mishra (1991) reported that K application improved the crop quality as frond length, height, girth, number of leaves, nut and volume of husked and unhusked nuts and copra weight per nut. K application also enabled coconut to get through the dry season more easily. Thus K is the most dominant nutrient element in the mineral nutrition of coconut palm.

2.1.4. Ca nutrition of the palm

Studying the effect of nutrients on coconut seedlings in India, Pillai (1959) reported that application of lime did not influence the growth of seedlings except in the case of those receiving N and P. Calcium as a nutrient is particularly important in the acid laterite soils where it increases phosphate availability.

Manicot et al. (1979 b) in their comprehensive review on mineral nutrition of coconut reported that application of Ca to tall coconuts in Ivory Coast in the form of $CaCO_3$ for four years did not modify the Ca levels. They found that no improvement on growth or yield could be expected from calcic fertilizer application.

Cecil (1988) through his crop removal studies suggested that the quantitative requirement of Ca for coconut palm is much higher than that of P and it is mainly concerned with the proper growth and functioning of stem and leaves rather than on productivity of nuts. He also suggested that the critical level of Ca in frond 14 is 0.3 per cent.

2.1.5. Mg nutrition of the coconut palm

Magnesium is a constituent of chlorophyll and is very important in the nutrition of coconut palm. One of the most common mineral deficiencies encountered in coconut in many of the coconut growing countries is that of Mg.

Bachy (1963) reported that Mg was one of the limiting elements in the nutrition of seedlings and young palms especially when the soil supply of Mg is low. Studies conducted in West Africa showed that application of Mg along with P and K fertilizers brought about highly significant improvement in the vigour of seedlings in the nursery stage. Fremond et al. (1966) recommended application of 60 g magnesium sulphate per plant in the nursery along with similar quantities of double super phosphate and muriate of potash.

Specific instances of absolute Mg deficiency condition in the soil were reported in Srilanka by De Silva (1966), in India by Cecil et al. (1963) and Varghese (1966) and in West Africa by Brunin (1969). Application of magnesium sulphate/dolomite improved visual symptoms such as yellowing and increased yield in such situations.

Mathew (1977) reported the importance of Mg in coconut nutrition and pointed out that imbalance in K-Mg ratio resulted in yellowing of leaves and reduction in yield. Clarson et al. (1986) reported that application of Mg at the rate of 100g per palm had maximum response on coconut yield in Kanyakumari district of TamilNadu. Cecil (1988) observed Mg as one of the limiting nutrient elements in the nutrition of coconut which could enhance the yield as high as 40 per cent. Further Cecil and Khan (1991) reported that Mg was a limiting nutrient in coastal sandy and laterite soils and correction of Mg deficiency led to 30 to 35 per cent increase in yield.

2.1.6. S nutrition in coconut palm

Sulphur has beneficial effects on the setting of fruits, hardening of kernel and on copra qualities. Sulphur deficiency in coconut was reported in many widely scattered areas of Papua and New Guinea (Southern, 1969) and Madagascar (Ollagnier and Ochs, 1972) which was characterised by severe chlorosis, poor yields and poor quality copra. Discussing the S nutrition of coconut, Cecil and Pillai (1976) opined that S deficiency was not an immediate problem for coconuts in the west coast of India. They recommended the inclusion of any one of the S containing fertilizers in the fertilizer schedule for coconut.

Wahid (1984) grouped S along with P, Ca and Mg that effect the yield only when their levels in the palm are too low for the satisfactory growth. De Silva et al. (1985) studied the S nutrition of coconut and reported that S content in the sixth leaf from the apex of coconut palms was found to be the most sensitive index to S treatments.

Pillai et al. (1975) reported that the 14th leaf S content ranged from 0.113 to 0.152 per cent. The results presented by Manicot et al. (1980 a) showed that the S content of frond 14 varied from 0.164 to 0.238 per cent for talls and 0.175 to 0.445 per cent for hybrids. They suggested a critical level of 0.15 to 0.20 per cent S in frond 14 while Magat (1979) suggested a critical level of 0.15 per cent.

2.1.7. Cl nutrition of coconut palm

Although there are large quantities of Cl in plant tissue, it was considered an element without specific importance until Broyer *et al*. established its essentiality in 1954. The importance of Cl nutrition to coconut palm was brought out by Ollagnier and Ochs (1971). They showed that oil palm and coconut gave significant yield increases to Cl application. They further emphasised high requirement of this element and suggested to rank Cl as an essential major nutrient for coconut. Uexkull (1971) and Magat *et al*. (1975) reported that coconut palms grown near to sea shore where Cl was sufficient were more productive than those found in low Cl inland areas.

Ouvrier and Ochs (1979) reported the high requirement of Cl for coconut and they reported that for the hybrid PB.121, the exhaust of Cl was equal to that of K. They arranged the nutrients according to their sequential importance for coconut palm as K> Cl> N> Ca> Na> Mg> S> P. Ollagnier et al. (1983) proposed a critical level of 0.5 per cent Cl in frond number 14 for the Ivory Coast.

The effect of Cl deficiency on stomatal function and water balance of coconut were studied by Braconnier and Dauzae (1990) and they reported that Cl deficient coconut was less drought tolerant. Magat *et al*. (1991) showed clear evidence of positive residual effects of Cl fertilizers at 0.8 kg Cl per tree in terms of nut production and copra for 3-5 years after regular fertilization of either KCl, NaCl or NH4Cl.

2.1.8. Fe nutrition of coconut palm

The diagnosis of Fe deficiency is tricky, as it has not been possible to define the critical level in the leaf with sufficient precision. Consequently, coconut palms on poor soils can show deficiency symptoms when the Fe level in leaf 14 is 45 ppm (Manicot, et al.1980 a). Ochs and Bonneau (1988) reported Fe deficiency in coconut palms on peat soils in Indonesia. The very characteristic symptom had been called 'peripheral leaf desiccation'. The symptoms were gradual yellowing of the entire leaflet, in longitudinal strips parallel to the veins. Iron sulphate applied at the rate of 5-10g per plant had a striking effect in regreening them (Manicot, et al. 1980 a).

2.1.9. Mn nutrition of coconut palm

Mn and Fe are interrelated in their metabolic functions with the effectiveness of one determined by the proportionate presence of other. Manicot et al. (1980 b) pointed out that manganese sulphate had no action in the absence of Fe fertilization and once the Fe and Mn deficiencies are corrected, N and K deficiencies appear. Manicot et al. (1980 b) also opined that it is difficult to define a critical level for Mn in coconut.

2.1.10. Zn nütrition of coconut palm

According to Manicot *et al*. (1980 b) the Zn contents vary from 15 ppm in the Ivory Coast to 24 ppm in Benin. Vijaya Raghavan *et al*. (1989) could receive response for soil application of 200g zinc sulphate per palm per year with recommended dose of NPK for a period of five years. Apart from ameliorating Zn deficiency, an yield increase of 49.7 per cent was recorded over control by them at Coconut Research Station, Veppankulam.

2.2. Foliar analysis

Foliar analysis has been recommended as one of the best methods for assessing the nutrient requirement of coconut. The pioneering works on foliar diagnosis in coconut were done by the scientists of IRHO in West Africa and they have standardised different aspects of foliar analysis as a diagnostic tool in coconut. Ziller and Prevot (1962) recommended the leaf lamina of the frond 14 as the index leaf for foliar analysis in coconut and defined the critical levels of different nutrient elements in this leaf.

Even though there are certain limitations, the excellent studies conducted by IRHO, Manicot et al. (1979 a, b, 1980 a, b) and the significant results reported by Magat (1979) sufficiently illustrated that leaf analysis is an efficient tool for predicting the fertilizer requirement of the palm. The 14th leaf of an adult palm (8 years and above) has been widely accepted as the standard leaf for foliar diagnostic studies under normal conditions. This leaf is considered as one which has attained physiological maturity, but has not entered the phase of senesence. For young palms upto four years of age the fourth leaf and for 5-7 years, the ninth leaf have been accepted for this purpose (Prevot and Bachy, 1962; Ziller and Prevot, 1962). According to Taffin and Rognon (1991), based on the age of the tree, leaf 4, 9 and 14 can be sampled.

2.3. Critical level

The term critical concentration indicates the optimum concentration of a given nutrient element in the sampled tissue below which the application of that nutrient in appropriate form is expected to result in increased yields. According to Prevot and Ollagnier, (1957) critical level of a nutrient means the concentration of that nutrient in the leaf above which an yield response from the element in the fertilizer applied is unlikely to occur.

Smith (1969) challenged the concept of independent critical levels of major nutrients in foliar diagnosis of coconut. According to him the yield was related to the interaction between nutrient elements. He also suggested that coconut yield was related to the ratio between foliar N and K. Fremond *et al*. (1966) on reviewing the results of twenty years of research on coconut carried out in different countries fixed the levels of foliar N, P, K, Ca and Mg as 1.8 to 2, 0.12, 0.8 to 1.0, 0.5 and 0.3 per cent, respectively, on dry matter basis.

Cecil (1984) reported that the N, P and K contents of (frond 14) healthy palms of high productivity were 1.93, 0.198 and 1.23 per cent respectively. In Malaya, Kanapathy (1971) suggested tentative optimum levels of 1.8 per cent N, 0.12 per cent P and 0.8 to 1.11 per cent K for the tall palms, and 1.9 to 2.0 per cent N, 0.12 per cent P and 0.75 to 1.0 per cent K for the dwarfs.

Von Uoxkull (1971) found that the foliar nutrient levels of palms yielding more than 100 nuts per year in Philippines were 1.96 per cent N, 0.1 per cent P and 1.26 per cent K. According to Wahid *et al*. (1974) the critical level of K is 0.8 to 1.0 per cent. Further Wahid (1984) grouped N, K and Cl as nutrient elements which are directly involved in coconut production and pointed out that 'chemical diagnosis' and correction of deficiencies based on foliar critical levels are effective only in the case of these elements while visual diagnosis is the most practical approach in the detection of deficiency of other nutrient elements viz. P, Ca, Mg and S.

In Jamaica the foliar contents (frond 14) of N and K were lower than the IRHO levels, while P content fully agreed with the 0.12 per cent level (Barrant, 1977). The mean values of N, P and K ranged from 1.54 to 1.88, 0.1 to 0.16 and 0.63 to 0.93 per cent respectively. Gopi and Jose (1983) worked out the critical level of N and K in the second leaf as 3.31 per cent and 2.17 per cent respectively.

The critical levels of NPK adopted at present in Philippines are 1.8 per cent N, 0.12 per cent P and 0.8 to 1.0 per cent K which are the same as those suggested by IRHO, Paris (Magat,1979).

Manicot _et_ _al_. (1979) suggested that a Ca level of 0.3 to 0.4 per cent of dry matter in frond number 14 was satisfactory and no further improvement in development or yield could be expected from calcic fertilizer application. For Mg the critical level suggested by them is 0.24 per cent for talls and 0.2 per cent for hybrids. Cecil (1988) suggested that Mg saturation of 15-20 per cent of the exchange complex and exchangeable Mg/K ratio of 2 to 2.5 in the soil and foliar level of 0.2 per cent Mg in frond 14 may be considered as critical for regulating Mg nutrition of the palm.

Pushpangadan (1986) suggested the standard critical level of major nutrients in frond 14 as N-1.8 to 2.0 per cent, P-0.12 per cent, K-0.8 to 1.0 per cent, Ca-0.3 per cent and Mg-0.2 per cent.

The average total S content in frond number 14 reported by Pillai et al. (1975) ranged from 0.113 to 0.152 per cent. The results reviewed by Manicot et al. (1980) showed that the S content of frond 14 varied from 0.164 to 0.238 per cent for talls and 0.175 to 0.445 per cent for hybrids. They suggested a critical level of 0.15 to 0.2 per cent S in frond 14 while Magat (1979) suggested a critical level of o.15 per cent.

The high requirement of Cl for coconut suggested to rank this element as an essential major nutrient for coconut and oil palm (Ollagnier and Ochs, 1971). They proposed the critical level as 0.5 to 0.6 per cent. Magat et al. (1988) suggested a critical level of 0.7 to 0.8 per cent Cl in coconut seedlings. Magat (1979) and Margate et al. (1979) suggested the critical level of Cl (frond 14) at 0.5 to 0.55 per cent for adult palms.

2.4. Diagnosis and Recommendation Integrated System (DRIS)

Foliar analysis can be a useful tool for assessing plant nutrient status only if adequate procedures are available for making diagnosis from analytical data. Because of the dynamic nature of foliar composition, which is strongly influenced by aging process as well as interactions affecting nutrient uptake and distribution, foliar diagnosis can become a complex exercise.

Diagnosis and Recommendation Integrated System (DRIS) is an alternative approach which was evolved from physiological diagnosis (Beaufils, 1957) that uses nutrient ratios rather than concentration themselves to interpret tissue analysis. Recently this has received considerable attention since being developed by Beaufils (1973) at the University of Natal, South Africa.

It is a comprehensive system which identifies all the nutritional factors limiting crop production and in so doing increases the chances of obtaining high crop yield by improving fertiliser recommendation (Samuel, et al. 1985). Index values which measures how far a particular nutrient in the leaf or plant are from the optimum are used in the calibration to classify yield factors in order of limiting importance. Several advantages of this method over the conventional method of critical level approach have been reported. These include the use of the data in assessing nutrient balance in plant tissue, identification of not only the most limiting element, but the order in which the other elements would likely become limiting, the ability to diagnose the plant nutrient need much earlier in the life span of the crop than the critical level method allowing remedial steps to be taken earlier, greater accuracy in diagnosis and relatively more freedom from the effect of some of the sampling variables, such as the age of the plant part, geographical location etc.

Diagnosis and Recommendation Integrated system has been successfully applied to several crops viz., corn, soyabean and wheat (Sumner, 1977), sugarcane, (Elwali and Gascho, 1984; Jones and Bowen 1981), potato,(Johnson and Sumner, 1980; Mackay et al. 1987 and Sharma, 1991).

The Diagnosis and Recommendation Integrated System approach developed norms from data banks of observations representative of a particular cropping system, consisting of a minimum of tissue nutrient content and associated yields (Sumner, 1990). The norms which are used as reference standards against which samples to be diagnosed are compared, are calculated as the means of the various forms expressing the nutrients (N/P, N/K, K/P etc.) for a high yielding population of plants. The DRIS indices calculated measures the deviations of various forms of expressions in the tissue under diagnosis from their respective mean (norm) values.

2.4.1. DRIS norm development

The first step in implementing DRIS is the establishment of standard values or norms. The DRIS utilises a survey approach (Beaufils, 1973) for norm determination that is based on crop response model (Sumner and Farina, 1986).

In DRIS, the population of observations are divided into two subgroups viz., the low and high-yield groups and then mean values of high-yield groups is taken as estimates of tissue parameter optima. In addition the coefficients of variation of the high-yielding data provide a measure of the relative spread or breadth of the yield response surface at upper yield levels (Walworth and Sumner, 1987).

The actual cut-off value used to divide low and high-yield groups is not critical as long as the high-yield data remains normally distributed. Davee et al.(1986) defined high-yield group as population with yield one standard deviation above mean yield and low-yield groups as population with yield one standard deviation below mean yield.

For each pair of nutrients there are three forms of expressions that may be considered. N and P for example can be related as the ratio N/P, its inverse P/N or the product N x P. In DRIS calculation only one expression is used to relate each nutrient pair. The selection of this is done by comparing the variance of the low-yielding group to that of the high-yielding segment of the population. The form of expression (N/P, P/N or NxP) selected for use in DRIS computation is that with the largest variance ratio (Walworth and Sumner, 1987).

2.4.2. The DRIS chart

In the simplest case the DRIS norms of three selected nutrients can be related to one another in charts called DRIS chart (Beaufils, 1973; Sumner, 1982). The point of intersection of the three axis corresponds to the mean value for the high yielding population for each form of expression (Fig 1). This is the composition desired in order to increase the chance of obtaining a high yield. The diameter of the circle is set as 4 SD/3 (Beaufils, 1971) where SD is the standard deviation of the high-yielding subpopulation. A plant composition falling within the inner circle would be considered to be balanced. As one moves away from the central zone in any axis the degree of imbalance between the two elements increases. This zone of imbalance is divided into two sub zones, the first being a zone of light to moderate imbalance which is encompassed by the outer of the concentric circle, which has a diameter of 8 SD/3. Beyond this is the zone of marked imbalance.

2.4.3. DRIS indices

The use of DRIS chart enables one to make diagnosis of three nutrients. DRIS also provides a mathematical means of ordering a large number of nutrient ratios into nutrient indices that can be easily interpreted. A nutrient index is a mean of functions of all ratios containing a given nutrient. The details of computation of DRIS indices are given under materials and methods.

2.4.4. Nutrient index interpretation

Because the value of each ratio function is added to one index sub total and subtracted from another prior to averaging, all indices of a particular sample are balanced around zero. The more negative an index, the more lacking is the nutrient it represents relative to other nutrients used in the diagnosis. Alternatively a large positive nutrient index indicates that the corresponding nutrient is present in relatively excessive quantity.

In a plant sample with optimal nutrient balance, all nutrient indices would equal to zero. However, it is important to recognize that an individual nutrient is not necessarily present in optimum concentration even if its index equals zero. If for instance, results of a diagnosis were as follows:

Nutrient	N	P	K	Ca
Index	-14	0	+7	+7

One could accurately say that, of all the nutrients tested, N had the most negative index and hence least abundant and was likely to be yield limiting if nutrition were governing growth. Although P index equals zero, it was relatively less abundant than K and Ca, and was the most needed nutrient in this diagnosis. K and Ca were excessive relative to N and P. In this example, K and Ca may have actually been more yield limiting than P. However, because nutrients can in practical terms be added and not taken away the recommendation from this diagnosis includes supplementing the deficient N and to a lesser extent P, eventhough the P index is zero (Walworth and Sumner, 1987).

Some measure of the total nutrient balance in a plant may be indicated by the sum of the nutrient indices irrespective of the sign which is called the nutrient imbalance index. When the sums of the DRIS indices are large, one or more of the measured factors limits yield. Higher yields can result only when sum of indices is small, although low yields may still occur if other factors are limiting.

2.4.5. Testing DRIS norms

DRIS norms developed can be tested to ensure validity and accuracy (Walworth and Sumner, 1987). To do this, DRIS diagnosis are usually conducted on field or green house grown plants selected from factorially designed fertiliser trials. It is imperative that these data are independent from those used to generate the norms and coefficient of variations used in index calculations. The following procedure is suggested by Walworth and Sumner,(1987). First using data from an experiment in which yield responses have been obtained to the nutrient being studied, plants from the control or lowest treatment level are diagnosed and the most needed nutrients determined. Then the treatment with addition prescribed by the initial diagnosis is located and the yields are compared. If the yield increased when the appropriate treatment is applied, then the diagnosis is considered as success, if not it is considered a failure. After this the testings can be continued with an evaluation of the nutritional status of the second nutrient and so forth.

2.4.6. Comparison of DRIS and other diagnostic systems

Comparison of DRIS with other diagnostic systems like critical value or sufficiency range method has been done by many workers (Sumner, 1983 ; Walworth and Sumner, 1987). The critical value and sufficiency range systems are general approaches with no specific guidelines for standard value generations, although the accuracy of both these systems is to some extent dependent upon this process.

In most comparisons of diagnostic capabilities of critical value or sufficiency range systems and DRIS, tissue sampling has been done at a specific stage of growth. Even under these conditions DRIS usually maintains slightly higher diagnostic precision. According to Sumner,(1979) DRIS based treatment resulted in 39 successes and 12 failures whereas treatments based on critical values resulted in 22 successes and 11 failures in the case of Potato. The corresponding figures for sugarcane were 38 successes and 13 failures with DRIS, 20 successes and 9 failures when using critical values. For corn 166 successes and 24 failures were recorded with DRIS, whereas 133 successes and 34 failures with critical value system (Walworth and Sumner, 1987).

Elwali and Gascho (1984) reported that sums of DRIS indices irrespective of sign for sugarcane were significantly decreased when fertilization was based on DRIS rather than on critical values. Yields of both cane and sugar were significantly improved when DRIS recommendations were followed.

2.4.7. DRIS norms developed in crop plants

DRIS norms have been developed for corn, soyabean and wheat and the interpretation of tissue analysis by DRIS approach offered several distinct advantages over the critical nutrient level approach (Sumner, 1977 a, b and c). Preliminary DRIS norms for soyabean leaves were developed from 1245 sets of data on elemental NPK by Sumner (1977 a). The results indicated that the diagnosis can be made irrespective of varieties and age at which the leaf is sampled. The advantage of DRIS in predicting nutrient imbalances even when the nutrient concentration in the plant is in or above critical level is illustrated.

Sumner (1979) critically evaluated the precision and flexibility of different foliar techniques in making a valid diagnosis of nutrient imbalances. Comparison of diagnostic precision between critical level and DRIS approach was made using data from various field experiments with corn, soyabean, sugarcane and potatoes and opined that DRIS is superior to critical value approach.

Hockman *et al*.(1979) developed DRIS norms in Fraser fir christmas trees in Watauga and the preliminary evaluation of DRIS performance on the 79 trees suggested that assessments of nutrition balance as well as an examination of individual nutrient concentrations are needed to diagnose the nutrient status.

Johnson and Sumner, (1980) developed foliar diagnostic norms for potato from 745 sets of elemental leaf N, P and K compositions and corresponding yield. The advantage of DRIS approach over critical level approach was illustrated. Mackay *et al*. (1987) and Sharma,(1991) also developed foliar diagnosis norms for Potato. Sharma,(1991) reported that DRIS assessed the nutrient balance in potato and identified not only the most limiting elements, but also the order in which other elements would become limiting.

The usefulness of DRIS approach was tested for pineapple by Langenegger and Smith (1978) and in grapes by

Chithirai Selven et al. (1984). Bever *et al*. (1984) had derived DRIS norms for valencia orange and reported that DRIS diagnosis generally agreed with diagnosis made by sufficiency range method.

Beverly *et al*.(1986) derived DRIS norms using data bank of about 3500 tissue samples for evaluating the status of soyabean and the DRIS diagnosis generally agreed with those obtained by sufficiency range method. He also reported geographic differences in DRIS norms and indicated that regional deviations of diagnostic values may be necessary.

Amundson and Kochler, (1987) observed significant sampling date/time dependence for the DRIS norms derived for winter wheat grown in Eastern Washington and opined that DRIS procedure may not be independent of the age of the plant. Paul and Wells, (1986) developed DRIS norms for rice and tested its accuracy by applying the DRIS predicted nutrient recommendations.

Davee *et al*. (1986) had used DRIS to evaluate the mineral status of "Royal Ann" sweet cherry trees. Standard ratios were developed and DRIS indices for each nutrient element were calculated. Nutritional imbalance indices were worked out as the sum of DRIS indices irrespective of sign. They reported that trees with high nutrient imbalance index were consistently low yielding. Subbiah and Sunderarajan, (1987) applied DRIS for interpreting leaf nutrient ratios of solanaceous vegetables like brinjal and tomato. Synder and Kretschmer (1988) successfully applied the DRIS to bahia grass using relatively small data base and a visual quality rating to evaluate crop performance. Payne et al. (1990) also developed DRIS norms for bahia grass grown under a vide range of situations and reported that DRIS norms developed can provide very useful information.

Savoy et al. (1989) developed preliminary DRIS norms and verified its accuracy in diagnosing N and P deficiency and sufficiency in dallis grass. According to Timothy et al. (1988) DRIS serves best as a supplement to sufficiency range based interpretations providing additional information when severe imbalances exist in sweet cherry and hazelnut.

Kim and Leech, (1986) employed DRIS methods to diagnose nutrient balance through foliar analysis on hybrid poplar clone, and opined that the DRIS norms could be used for diagnosing the foliar nutrient balance. Walworth et al. (1986) developed DRIS norms for alfalfa grown on two highly weathered soils in Georgia and reported that some regionality exists in DRIS norms for alfalfa. Sanchez et al 1991 derived DRIS norms for crisphead lettuce in Florida and obtained correct predictions for K response.

Khan *et al*. (1988) has tested the efficiency of predicting nutrient imbalances and deficiencies in coconut by DRIS. DRIS indices indicated marked deficiency for N. The foliar levels of K which were below the suggested critical level did not give any negative index. According to them nutrient applications for coconut can be tailored to the optimum needs of production based on DRIS norm developed. Prabha Kumari *et al*. (1993) tested the efficiency of DRIS in predicting the nutrient imbalances and deficiencies in continuously fertilised coconut palms using the data derived from a 3^3 confounded NPK factorial experiment in coconut. In both these cases, only a limited number of palms from a single location were used and as such the DRIS norms reported were not much useful. Thus DRIS norms have been published for a wide range of crop plants though norms for some of these species are based on using limited data.

Materials and Methods

3. MATERIALS AND METHODS

For developing the Diagnosis and Recommendation Integrated System (DRIS) in coconut the palms maintained at three research stations of the Kerala Agricultural University namely, Coconut Research Station, Balaramapuram; Agricultural Research Station, Mannuthy and Regional Agricultural Research Station, Pilicode, were used. The geographical locations of these centres have humid tropical climate. These centres provided coconut populations with large variations in yield which suited well for the development of DRIS. Secondly yield data of individual palms for the past several years were available at these centres. Thirdly these centres represented the southern, central and the northern parts of Kerala and fourthly, they also provided two important soil types namely, laterite (Ultisol) and red sandy loam (Alfisol) on which coconut is grown in the state. Lastly, in all the three centres, West Coast Tall (which is the most widely cultivated variety) palms, are available in large numbers.

The palms selected for the experiment were middle-aged (30 to 40 years old) and were grown under rainfed condition. These palms were receiving fertilizers and other management practices according to the package of practices recommendations of the Kerala Agricultural University (Anon. 1986).

The yield data used in the computation of DRIS norms were the means of the yields recorded by the individual palms for the past six consecutive years (from 1986 to 1991). Even number of years was considered for the computation of mean yields to eliminate the effect of alternate bearing tendency, if any, in the population on the yield data.

A. Regional Agricultural Research Station, Pilicode

The Regional Agricultural Research Station Pilicode is located at 13^{o} N latitude and 70^{o} E longitude. The station lies at an altitude of 15 m above mean sea level. The area where the station is located is having an average slope ranging from 2 to 4 percent.

The average maximum temperature is 32.8^{o} C while the minimum temperature is 20.2^{o} C. The mean annual rainfall recorded at this station ranges from 2000 mm to 2500 mm. The mean monthly averages of temperature, relative humidity, rainfall and the number of rainy days are given in Appendix 1. The soil type at this station is laterite (Ultisol).

Three hundred and thirty palms were selected for the study from this station. The yield of the selected palms ranged from 5.8 to 153 nuts per palm per year

B. Agricultural Research Station, Mannuthy

The Agricultural Research Station Mannuthy is located at 12° 32' latitude and 74° 20' E longitude. The station lies at an altitude of 22 m. above mean sea level. The mean annual rainfall ranges from 1500 to 1800 mm. The average maximum temperature is 34.5° C while the minimum temperature is 21.1° C. The mean monthly averages of temperature, relative humidity, rainfall and the number of rainy days are given in Appendix 2. The soil type at this station is laterite (Ultisol).

One hundred and seventy palms were selected for the study from this station. The palms were selected in such a way as to get a wide range in annual yield ranging from 8.4 nuts to 137.7 nuts per annum.

C. Coconut Research Station, Balaramapuram

The Coconut Research Station, Balaramapuram lies at 8° 29' N latitude and 76° 57' E longitude and 64m above the mean sea level. The area where the station is located is having an average slope of one to three percent. The mean annual rainfall ranges from 1200 to 1500 mm. The average maximum temperature is 30.7° C while the minimum temperature is 23.4°C. The mean monthly averages of temperature, relative humidity, rainfall and the number of rainy days are given in Appendix 3. The soil at this station is red sandy loam (Alfisol).

Three hundred palms were selected for the study from this station. The individual palm yield ranged from 28.3 to 162.7 nuts per year.

In order to test the accuracy and validity of the foliar diagnosis made through DRIS, palms under an on-going 3^3 NPK fertilizer experiment at this station was used. This field trial was a factorial experiment testing three levels each of N, P and K. The details of the experiment are as follows.

Design	: 3^3 confounded factorial
Total number of treatments	: 27 (N, P and K each at three levels)
Number of replications	: 2
Number of blocks	: 6
Total number of plots	: 54
Number of plots per block	: 9
Spacing	: 7.5m x 7.5m
Number of experimental palms per plot	: 4
Treatments confounded	: NPK^2 in replication 1
	NP^2K^2 in replication 2
Coconut variety	: West Coast Tall
Date of planting	: 17-6-1964

Levels of nitrogen (g N per palm per year)

N0	:	0
N1	:	340
N2	:	680

Levels of phosphorus (g P_2O_5 per palm per year)

P0	:	0
P1	:	225
P2	:	450

Levels of potassium (g K_2O per palm per year)

K0	:	0
K1	:	450
K2	:	900

Nitrogen, phosphorus and potassium were applied through ammonium sulphate (20.5% N) super phosphate (18% P_2O_5) and muriate of potash (60% K_2O) respectively right from the beginning of the experiment and no organic matter source was included in the fertilizer schedule. The palms were 28 years old when they were made use for the present study.

3.2. Collection of leaf samples

Leaf samples were collected from the 14th frond as suggested in the sampling procedure by Fremond et al.,(1966). Fourteenth leaf starting from the first fully opened one was sampled from each selected palm.

Leaf samples were collected from 7 AM to 11 AM during the month of April- May 1992. Five leaflets from either side of the middle portion of the leaf were separated. Only the middle portion of the leaflet after discarding about 30 cm of the either end was considered.

The midrib of each leaflet was removed and only the leaf lamina was taken. The leaf laminae were cleaned with moist cotton to remove dust, cut into small pieces and dried in a hot air oven at 70 + or $-2^{\circ}C$. The dried samples were powdered in a mill with stainless steel blades and stored in plastic bottles until analysis.

3.3. Collection of soil samples

Representative soil samples from each station were drawn from 0 to 50 cm depth at a lateral distance of one metre from the palm. Soils were sampled from the basins of ten randomly selected trees from each station to get a representative sample. The soil samples were collected during April-May 1992 prior to the onset of monsoon season. Collected soil samples were air-dried and sieved through 2-mm mesh and stored in plastic bottles until analysis.

3.4. Analytical methods

Leaf samples were analysed for N, P, K, Ca, Mg, S, Fe, Zn, Mn and Cl. Nitrogen was estimated by modified Kjeldahl's method as described by Jackson (1973). Determination of the other nutrients except Cl was done after digestion with 2:1 HNO_3-$HClO_4$ mixture (Johnson and Ulrich, 1959). Phosphorus in the digest was determined by the vanadomolybdate yellow color method. K was estimated using flame photometer (Jackson, 1973). Calcium, Mg, Fe, Mn and Zn in the digest were estimated using an atomic absorption spectrophotometer (Perkin Elmer, USA). Sulphur in the digest was estimated turbidimetrically using $BaCl_2$ (Jackson, 1973).

Chlorine was estimated titrimetrically after digestion (Anon. 1972). Chlorine in plant sample was determined by destroying the organic matter content in the sample by digestion with nitric acid and potassium permanganate in the presence of excess silver nitrate. Chloride is precipitated as silver chloride and the excess silver is titrated with potassium thiocynate in the presence of acetone using ferric iron as the indicator. The analytical procedures adopted are outlined in Table 1.

Soil samples representative of each station were analysed for pH, organic carbon, available P, K, Ca, Mg, S, Fe, Zn and Mn to get basić soil data of the different sampling areas. Organic carbon was estimated titrimetrically by Walkley - Black method, available P using Bray-1 extractant and available K by extraction with N ammonium acetate(pH 7). Exchangeable Ca and Mg were estimated after extraction with N ammonium acetate (pH 7). Available S was estimated turbidimetrically using Morgan's reagent as the extractant. Available Fe, Zn and Mn were extracted using DTPA and were estimated using an atomic absorption spectrophotometer (Perkin Elmer, USA). The analytical procedures employed and their references are given in Table 2.

Table 1. Details of the methods followed in leaf analysis

Nutrient	Digestion procedure	Method of estimation	Instrument used	Reference
N	H2SO4 digestion	Distillation and titration	Titrimetric	Jackson (1973)
P	2:1 HNO3-HClO4 diacid digest	Vanadomolybdate yellow colour method	Spectrophotometer	"
K	"	Direct reading	Flame photometer	"
Ca	"	"	Atomic absorption spectrophotometer	"
Mg	"	"	"	"
S	"	Turbidimetric	Spectrophotometer	"
Fe	"	Direct reading	Atomic absorption spectrophotometer	"
Zn	"	"	"	"
Mn	"	"	"	"
Cl	HNO3- KMnO4	Titration	Titrimetric	Anon'(1972)

Table 2. Details of the methods followed in soil analysis

Soil characteristics	Extractant used	Method of estimation	Instrument used	Reference
pH	1:2.5 soil-water ratio	Direct reading	pH meter	Jackson (1973)
Organic carbon	-	Walkely-Black	Titrimetric	"
Available P	Bray-1	Molybdenum - blue	Spectrophotometer	"
Available K	N Ammonium acetate (pH 7)	Direct reading	Flame photometer	"
Exchangeable Ca	"	"	Atomic absorption spectrophotometer	"
Exchangeable Mg	"	"	"	"
Available S	Morgan's reagent	Turbidimetric	Spectrophotometer	"
Available Fe	DTPA	Direct reading	Atomic absorption spectrophotometer	Lindsay and Norvel (1978)
Available Zn	"	"	"	"
Available Mn	"	"	"	"

3.5. Computation of DRIS norms

The Diagnosis and Recommendation Integrated System (DRIS) approach uses nutrient ratios rather than the nutrient concentrations themselves. All possible combinations of nutrient ratios involving two nutrients and their inverses were worked out. DRIS norms were calculated using the method as described by Beaufils, (1973) and Walworth and Sumner (1987).

The population of the coconut palm was divided into two, namely, low-yielding and high-yielding subpopulations based on the criterion suggested by Davee et al., (1986). High-yielding subpopulation is constituted by trees with yields one standard deviation above the mean yield and low-yielding populations as those trees with yields one standard deviation below the mean yield. Depending on the objective of the study total population (population of palms from all the three locations taken together), the palm population of two locations or palm population of each location separately was used for the computation of DRIS norms.

Altogether 90 simple ratios involving two nutrients (including their inverse form) can be worked out for the ten nutrients namely, N, P, K, Ca, Mg, S, Cl, Fe, Mn and Zn. A PC/AT was used in all the computations. After computing these ratios for each sample in the low-and high-yielding subpopulation, their means for the two groups were determined. The nutrient ratios whose variance ratios for the two subpopulations varied significantly were selected for developing DRIS norms. In case a nutrient ratio and its inverse yielded significant variance ratios, the form which had the higher variance ratio was selected for the purpose. The individual nutrients were also considered for the computation of DRIS norm in the same way as the nutrient ratios.

The means of the nutrient ratios or individual nutrients for the high-yielding population formed the foliar diagnostic (DRIS) norms (Beaufils, 1973 and Walworth and Sumner, 1987).

3.6. DRIS chart .

The DRIS norms of any three selected nutrients can be related to one another in charts called DRIS charts for obtaining qualitative information on the order of requirement of the three nutrients. The point of intersection of the three axes in the DRIS chart correspond to the mean values for the high-yielding population for each form of expression. This is the composition desired inorder to increase the chance of obtaining a high yield.

3. 7. Computation of DRIS index

DRIS indexing provides a mathematical means of ordering a large number of nutrient ratios into nutrient indices that can be easily interpreted. DRIS indices were calculated using a formula that used the reference ratios, their standard deviations, and the observed ratios of the sample being evaluated (Walworth and Sumner, 1987). For the computation of DRIS indices, DRIS norms were determined first. Then they were used to generate indices by the following equations.

In the case for the hypothetical nutrients A through N

$$A\ index = \frac{(f(A/B) + f(A/C) + f(A/D) \ldots\ldots\ldots + f(A/N)}{z}$$

$$B\ index = \frac{(-f(A/B) + f(B/C) + f(B/D) \ldots\ldots\ldots + f(B/N)}{z}$$

$$N\ index = \frac{(-f(A/N) - f(B/N) - f(C/N) \ldots\ldots\ldots\ldots - f(M/N)}{z}$$

where, when $A/B > a/b$, $f(A/B) = ((A/B)/(a/b)-1)\ 1000/cv$

or, when $A/B < a/b$, $f(A/B) = (1-(a/b)/(A/B))\ 1000/cv$

in which A/B is the value of the ratio of the two elements in the tissue of the plant being diagnosed, a/b is the DRIS norm for that ratio, cv is the coefficient of variation associated with the norm, and z is the number of functions comprising the nutrient index. Values for the other functions, such as f(A/C), f(A/D), etc. are calculated in the same way as f(A/B), using the appropriate norms and coefficients of variation.

A nutrient index, then, is simply a mean of functions of all ratios containing a given nutrient. The components of this mean are weighted by the reciprocals of the coefficients of variation of the high-yielding populations from which the norms are developed. Therefore, if the expressions A/B and A/C both are used to generate an index for the nutrient A, their contribution to the index would depend on the coefficients of variation associated with their optima, which reflect the relative influence of these two expressions on crop yield.

3.8. Nutrient Imbalance Index

The nutrient imbalance index (NII) was calculated for 27 palms receiving three different levels of N, P and K under the permanent manurial trial at the Coconut Research Station Balaramapuram. This was worked out by taking the actual sum of the DRIS indices irrespective of sign. By using the NII, the nutritional imbalance of any desired palm can be obtained. The order of nutrient requirement in any palm can be found out from this, assuming that the most negative DRIS index value represented the most deficient situation and the most positive value represented the most sufficient situation.

Results

4. RESULTS

The data pertaining to the development of DRIS based on the chemical analysis of 800 leaf samples collected from coconut palms growing in three different locations namely, Pilicode, Mannnuthy and Balaramapuram are presented in this section. There were 330 samples from Pilicode, 170 samples from Mannuthy and 300 samples from Balaramapuram to give a total of 800 samples. The soil type at Pilicode and Mannuthy was laterite (Ultisol) while it was red sandy loam (Alfisol) at Balaramapuram.

4.1. Soil and foliar nutrient status

The general characteristics of the soils at the three locations are given in Table 3. The laterite soil at Pilicode is relatively more acidic than the others. The organic matter status of the soils was generally poor (organic C content being less than 1%). The red sandy loam soil at Balaramapuram had the lowest organic C content. Available P status of the soils of the three locations varied considerably, from 14.2 ppm for the Pilicode soil to 57.9 ppm for the Balaramapuram soil. Available K was less in Balaramapuram soil (82.5 ppm) compared to the Pilicode soil which registered the highest value of 375 ppm. A reverse trend was observed in the case of exchangeable Ca, Pilicode soil showing the lowest (70 ppm) and Balaramapuram the highest (256 ppm). Exchangeable Mg

Table 3. Characteristics of the soils at the three leaf sampling locations selected for the study

Property	Pilicode	Mannuthy	Balaramapuram
pH	5.20	5.50	5.60
Organic C	0.82	0.78	0.51
Available P	14.20	24.30	57.90
Available K	375.00	147.50	82.50
Exchangeable Ca	70.00	233.30	256.00
Exchangeable Mg	18.00	43.30	19.00
Available S	130.40	95.90	84.50
Available Fe	54.70	46.60	23.30
Available Zn	2.50	8.00	1.20
Available Mn	91.60	43.10	50.40

Note: Organic carbon expressed as percentage and the others in ppm.

was generally very poor in the three locations whereas the S status was considerably more. The soils were also rich in available Fe, Zn and Mn.

Data relating to the foliar nutrient status of the palms at the three sampling locations namely, Pilicode, Mannuthy and Balaramapuram are presented in Table 4. Balaramapuram population recorded the highest N content of 1.65% followed by Pilicode (1.52%) and Mannuthy (1.45%). Mean P content was also higher in the Balaramapuram population (0.18%). It was the lowest in the Pilicode population (0.12%). In the case of K, palms at Mannuthy recorded a mean value of 1.34% followed by Pilicode (1.29%) and Balaramapuram (1.24%). A perusal of the data given in Table 4 would also show that the lowest contents of Mg (0.17%) and S (0.10%) were recorded by Pilicode population and the highest by Balaramapuram population. Chlorine, Zn and Mn concentrations did not show much variation among the different locations.

4.2. DRIS norms

The data generated from the chemical analysis of the leaf samples were used to develop DRIS norms for coconut palm. The criterion used for deriving DRIS norms was that suggested by Beaufils (1973). To distinguish between the low- and high-yielding populations, mean plus standard deviation and mean minus standard deviation values were used (Davee et al. 1986). Thus the palms with yields equal

Table 4. Foliar nutrient composition of coconut palms at the three sampling locations

Nutrient	Pilicode	Mannuthy	Balaramapuram
N	1.52 (1.23-1.91)	1.45 (1.29-1.73)	1.65 (1.25-1.89)
P	0.12 (0.10-0.13)	0.17 (0.14-0.18)	0.18 (0.09-0.22)
K	1.29 (1.07-1.41)	1.34 (1.19-1.61)	1.24 (1.11-1.56)
Ca	0.3 (0.28-0.37)	0.32 (0.22-0.44)	0.27 (0.20-0.38)
Mg	0.17 (0.15-0.20)	0.2 (0.17-0.24)	0.21 (0.2-0.24)
S	0.1 (0.06-0.13)	0.14 (0.12-0.16)	0.19 (0.16-0.23)
Cl	0.62 (0.59-0.66)	0.65 (0.61-0.73)	0.64 (0.61-0.68)
Fe	280 (210-320)	420 (370-470)	220 (150-300)
Zn	22 (18-30)	20 (17-28)	21 (18-30)
Mn	230 (108-346)	204 (150-270)	230 (160-290)

Note: The concentrations of N, P, K, Ca, Mg, S and Cl are expressed in percentage and those of Fe, Zn and Mn in ppm.

Parentheses denote ranges

to or exceeding 85.9 nuts per year (i.e., 59.75 + 26.15) were considered as high yielding and those with 33.6 or less number of nuts per year (i.e., 59.75 - 26.15) were considered as low yielding. Based on this criterion there were 157 palms in the low yielding group and 130 palms in the high yielding group.

The means and variances of individual nutrients namely, N, P, K, Ca, Mg, S, Cl, Fe, Zn and Mn as well as their ratios (totalling 90 including inverse ratios) were worked out for the two subpopulations. The variance ratios were then computed for each nutrient and for each nutrient ratio to examine their statistical significance. Only those nutrients and nutrient ratios whose variance ratios were significant were considered for discriminating the low-yielding subpopulation from the high-yielding group. In case where statistical significance was obtained for a nutrient ratio and also for its inverse, the form which had a higher variance ratio was selected for the purpose.

Mean values of the selected individual nutrient(s) and nutrient ratio(s) of the high-yielding subpopulation formed the DRIS norms. The data relevant to DRIS norms are given in Appendix 4. Five nutrients namely, N, P, Ca, Mg and Cl and as many as 45 nutrient ratios were found to yield statistically significant variance ratios between the low- and high-yield groups. Among the nutrient ratios, 33 were selected on the basis of their higher variance ratios compared to the inverse forms. The data for the selected ratios and nutrient elements are presented in Table 5.

Among the nutrient elements, the mean values of N and Ca were found to be higher for the low-yield group than for the high-yield group while the reverse was true for P, Mg, and Cl. The nutrient ratios for low-yield group were higher than for high yield group in 26 cases . These ratios were N/P, N/Mg, N/S, N/Cl, N/Fe, N/Mn, P/S, K/N, K/Cl, K/Zn, K/Mn, Ca/N, Ca/S, Ca/Cl, Ca/Fe, Ca/Zn, Ca/Mn, Mg/S, Mg/Mn, Cl/Mg, Cl/S, Fe/S, Zn/Mg, Zn/S, Zn/Mn and Mn/S. The nutrient ratios which gave higher values for high-yield group were P/K, P/Ca, P/Fe, K/Fe, Mg/K, Mg/Ca and S/K.

4.3. DRIS chart

From the 33 nutrient ratios presented in Table 5, 31 DRIS charts involving selected three-nutrient combinations could be constructed. Data relevant for the construction of DRIS charts are presented in Table 6. The DRIS charts are presented only for the five most significant three-nutrient combinations namely, N-K-Cl, N-Mg-S, Ca-S-Cl, Cl-Mg-S, and Zn-Mg-S. The importance of N-K-Cl DRIS chart lies in the fact that these three nutrients are directly involved in coconut production.

It may be observed from Table 5 that 15 nutrient ratios namely, N/P, N/Mg, N/S, P/K, P/Ca, Ca/S, Ca/Cl,

Table 5. DRIS norms for coconut palm

Form of expression	Low yield group (A)			High yield group (B)			Variance ratio (SA/SB)
	Mean	Variance (SA)	CV (%)	Mean	Variance (SB)	CV (%)	
N	1.680	0.136	21.96	**1.520**	0.067	16.97	2.04
P	0.160	0.001	23.75	**0.190**	0.002	24.61	1.52
Ca	0.309	0.008	28.16	**0.245**	0.005	27.35	1.68
Mg	0.191	0.001	19.37	**0.199**	0.001	13.07	1.94
Cl	0.627	0.010	15.94	**0.638**	0.006	12.38	1.62
N/P	11.680	19.430	37.76	**8.360**	5.990	29.27	3.24
N/Mg	9.230	11.020	35.97	**7.680**	1.790	17.42	6.15
N/S	17.330	100.470	57.81	**9.460**	10.760	34.67	9.34
N/Cl	2.740	0.600	28.47	**2.430**	0.354	24.53	1.69
N/Fe	59.120	843.900	49.14	**57.940**	480.030	37.81	1.76
N/Mn	96.020	1478.700	40.04	**80.120**	981.500	39.10	1.51
P/K	0.120	0.002	32.50	**0.167**	0.005	43.21	3.47
P/Ca	0.530	0.026	30.57	**0.537**	0.080	33.74	3.03
P/S	1.440	0.291	37.43	**1.160**	0.148	33.12	1.97
P/Fe	5.250	5.620	45.14	**7.410**	11.280	45.32	2.00
K/N	0.868	0.142	43.43	**0.863**	0.100	36.70	1.42
K/Cl	2.200	0.431	29.81	**1.980**	0.293	27.32	1.47
K/Fe	45.870	363.540	41.57	**49.560**	713.200	53.89	1.96
K/Zn	695.600	97362.000	44.85	**645.900**	59775.300	37.86	1.63
K/Mn	81.720	2097.400	56.04	**68.700**	1364.300	53.78	1.54
Ca/N	0.195	0.006	40.00	**0.168**	0.004	38.31	1.45
Ca/S	2.990	2.140	48.82	**1.580**	0.660	51.48	3.22
Ca/Cl	0.508	0.031	34.65	**0.390**	0.015	31.02	2.13
Ca/Fe	10.530	21.450	43.96	**9.200**	12.520	38.45	1.71
Ca/Zn	155.800	3962.900	40.37	**124.900**	2037.600	36.14	1.95
Ca/Mn	17.380	50.680	40.97	**12.290**	13.790	30.20	3.68
Mg/K	0.150	0.002	30.67	**0.172**	0.003	34.01	1.60
Mg/Ca	0.647	0.026	25.04	**0.862**	0.044	24.25	1.67
Mg/S	1.830	0.625	43.22	**1.250**	0.176	33.76	3.54
Mg/Mn	11.150	22.950	43.05	**10.530**	15.100	36.88	1.52
S/K	0.095	0.002	48.42	**0.154**	0.005	47.82	2.52
Cl/Mg	3.440	1.010	29.07	**3.260**	0.369	18.62	2.75
Cl/S	6.240	9.240	48.72	**4.100**	2.900	41.48	3.19
Fe/S	0.313	0.024	49.20	**0.190**	0.012	57.60	1.97
Zn/Mg	0.012	0.221*	39.17	**0.011**	0.080*	27.36	2.54
Zn/S	0.021	2.000*	61.90	**0.013**	0.400*	43.18	5.12
Zn/Mn	0.120	0.003	41.67	**0.108**	0.002	38.61	1.44
Mn/S	0.194	0.013	59.28	**0.137**	0.006	55.40	2.30

CV : Coefficient of variation

* : $X 10^{-4}$

Table 6. Relevant data for the construction of DRIS charts involving selected three-nutrient combinations

Sl. no.	Nutrient combination	Nutrient ratio	DRIS norm	4SD/3	8SD/3
1	N-K-Cl	N/Cl	2.430	0.800	1.600
		K/N	0.860	0.420	0.840
		K/Cl	1.980	0.720	1.440
2	N-K-Fe	N/Fe	57.940	29.210	58.430
		K/N	0.863	0.420	0.840
		K/Fe	49.560	35.610	71.220
3	N-K-Mn	N/Mn	80.120	41.730	83.470
		K/N	0.863	0.420	0.840
		K/Mn	68.700	49.200	98.400
4	N-P-S	N/P	8.360	3.270	6.530
		N/S	9.460	4.370	8.750
		P/S	1.160	0.510	1.020
5	N-P-Fe	N/P	8.360	3.270	6.530
		N/Fe	57.940	29.210	58.430
		P/Fe	7.410	4.480	8.960
6	N-Mg-S	N/Mg	7.680	1.790	3.580
		N/S	9.460	4.370	8.750
		Mg/S	1.250	0.560	1.120
7	N-Mg-Cl	N/Mg	7.680	1.790	3.580
		N/Cl	2.430	0.800	1.600
		Cl/MG	3.260	0.810	1.620
8	N-S-Cl	N/S	9.460	4.370	8.750
		N/Cl	2.430	0.800	1.600
		Cl/S	4.100	2.270	4.530
9	N-Mg-Mn	N/Mg	7.680	1.790	3.580
		N/Mn	80.120	41.730	83.470
		Mg/Mn	10.530	5.170	10.340
10	N-S-Fe	N/S	9.460	4.370	8.750
		N/Fe	57.940	29.210	58.430
		Fe/S	0.190	0.150	0.290
11	N-S-Mn	N/S	9.460	4.370	8.750
		N/Mn	80.120	41.730	83.470
		Mn/S	0.137	0.100	0.200
12	P-Ca-S	P/Ca	0.537	0.380	0.750
		P/S	1.160	0.510	1.020
		Ca/S	1.580	1.090	2.180
13	P-Ca-Fe	P/Ca	0.537	0.380	0.750
		P/Fe	7.410	4.480	8.960
		Ca/Fe	9.200	4.720	9.440
14	P-S-Fe	P/S	1.160	0.510	1.020
		P/Fe	7.410	4.480	8.960
		Fe/S	0.190	0.150	0.290
15	P-K-Fe	P/K	0.167	0.090	0.190
		P/Fe	7.410	4.480	8.960
		K/Fe	49.560	35.610	71.220

Contd...

Sl. no.	Nutrient combination	Nutrient ratio	DRIS norm	4SD/3	8SD/3
16	Ca-N-S	Ca/N	0.168	0.090	0.170
		Ca/S	1.580	1.090	2.180
		N/S	9.460	4.370	8.750
17	Ca-N-Cl	Ca/N	0.168	0.090	0.170
		Ca/Cl	0.390	0.160	0.320
		N/Cl	2.430	0.800	1.600
18	Ca-N-Fe	Ca/N	0.168	0.090	0.170
		Ca/Fe	9.200	4.720	9.890
		N/Fe	57.940	29.210	83.470
19	Ca-N-Mn	Ca/N	0.168	0.090	0.170
		Ca/Mn	12.290	4.950	9.890
		N/Mn	80.120	41.730	83.470
20	Ca-S-Cl	Ca/S	1.580	1.090	2.180
		Ca/Cl	0.390	0.160	0.320
		Cl/S	4.100	2.270	4.530
21	Ca-S-Fe	Ca/S	1.580	1.090	2.180
		Ca/Fe	9.200	4.720	9.440
		Fe/S	0.190	0.150	0.290
22	Ca-S-Zn	Ca/S	1.580	1.090	2.180
		Ca/Zn	124.900	60.170	120.340
		Zn/S	0.013	0.008	0.016
23	Ca-S-Mn	Ca/S	1.580	1.090	2.180
		Ca/Mn	12.290	4.950	9.890
		Mn/S	0.137	0.100	0.200
24	Ca-Zn-Mn	Ca/Zn	124.900	60.170	120.340
		Ca/Mn	12.290	4.950	9.890
		Zn/Mn	0.108	0.060	0.110
25	MG-K-Mn	Mg/K	0.172	0.080	0.160
		Mg/Mn	10.530	5.170	10.340
		K/Mn	68.700	49.200	98.400
26	Mg-Ca-S	Mg/Ca	0.862	0.280	0.550
		Mg/S	1.250	0.560	1.120
		Ca/S	1.580	1.090	2.180
27	Mg-Ca-Mn	Mg/Ca	0.862	0.280	0.550
		Mg/Mn	10.530	5.170	10.340
		Ca/Mn	12.290	4.950	9.890
28	Mg-S-Mn	Mg/S	1.250	0.560	1.120
		Mg/Mn	10.530	5.170	10.340
		Mn/S	0.137	0.100	0.200
29	Cl-Mg-S	Cl/Mg	3.260	0.810	1.620
		Cl/S	4.100	2.270	4.530
		Mg/S	1.250	0.560	1.120
30	Zn-Mg-S	Zn/Mg	0.011	0.004	0.008
		Zn/S	0.013	0.008	0.016
		Mg/S	1.250	0.560	1.120
31	Zn-Mg-Mn	Zn/Mg	0.011	0.004	0.008
		Zn/Mn	0.108	0.060	0.110
		Mg/Mn	1.530	5.170	10.340

Ca/Mn, Mg/S, S/K, Cl/Mg, Cl/S, Zn/Mg, Zn/S and Mn/S gave higher variance ratios than 2.04, the highest variance ratio obtained for an individual nutrient. Higher the variance ratios, greater is the discrimination between the low- and high-yield groups. Therefore, these 15 ratios are far more useful in developing DRIS charts than the other nutrient ratios or individual nutrients with lower variance ratios. From these 15 nutrient ratios, four DRIS charts can be constructed. These are for the three-nutrient combinations of N-Mg-S, Ca-S-Cl, Cl-Mg-S and Zn-Mg-S. The DRIS charts for these three nutrient combinations and that for N-K-Cl are presented in Figs. 1 to 5.

4.4. Test of the DRIS method

In order to test the accuracy of the diagnosis of nutritional imbalances by DRIS approach, DRIS indices for the ten selected nutrients were computed for palms receiving varying levels of NPK under a factorial experiment (Table 7). A nutrient index is a mean of functions of all ratios containing a given nutrient. It was observed that DRIS index for a nutrient varied not only with the applied level of that nutrient but also with the applied level of other nutrients. For example, the N index for N1P0K2 treatment was -9 while it was -16 for N1P2K2 treatment. Similarly, the K index for N1P0K0 was -38 while it was -168 for N1P2K0 treatment. When the

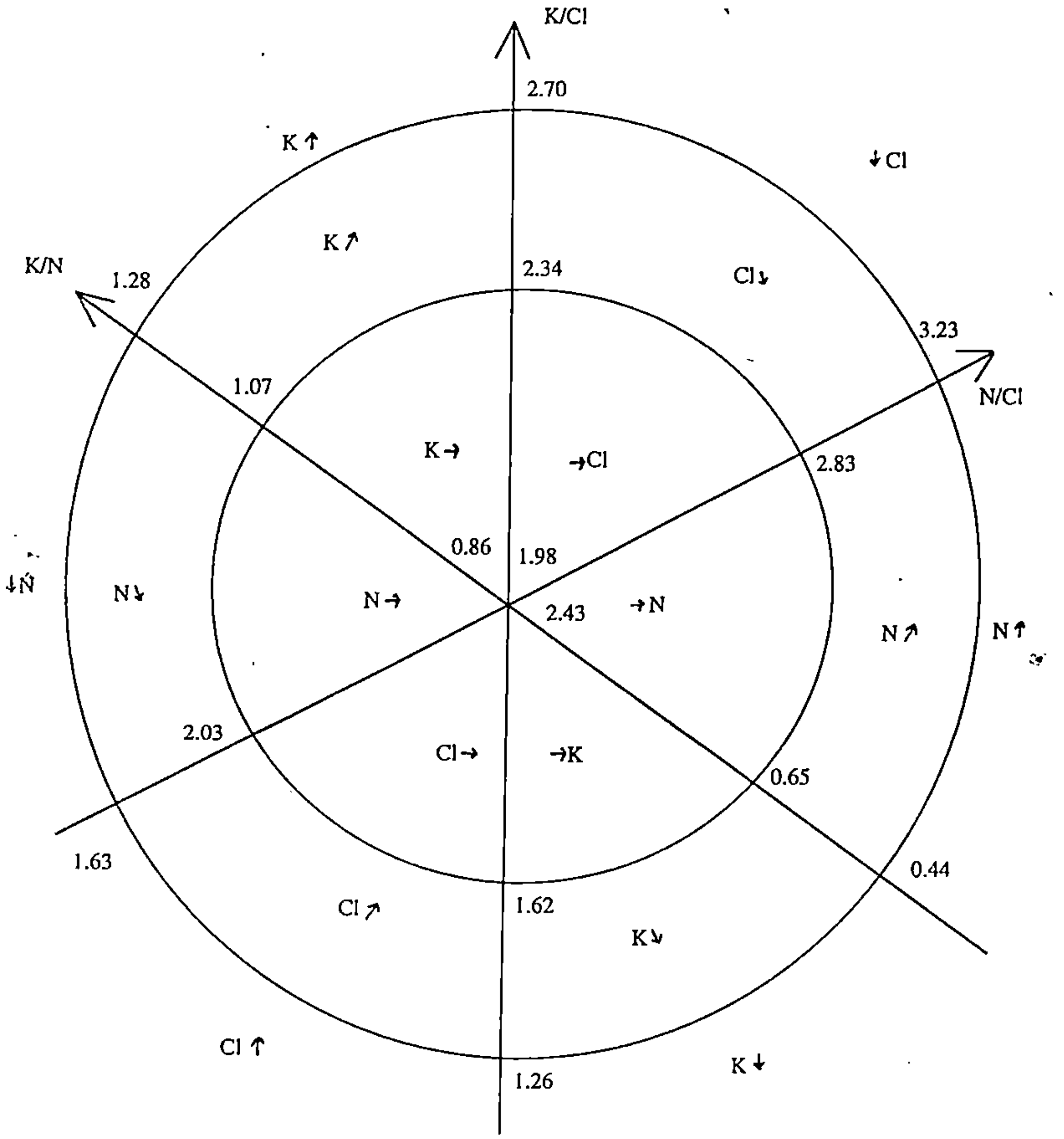

Fig. 1. DRIS chart for N, K and Cl in coconut

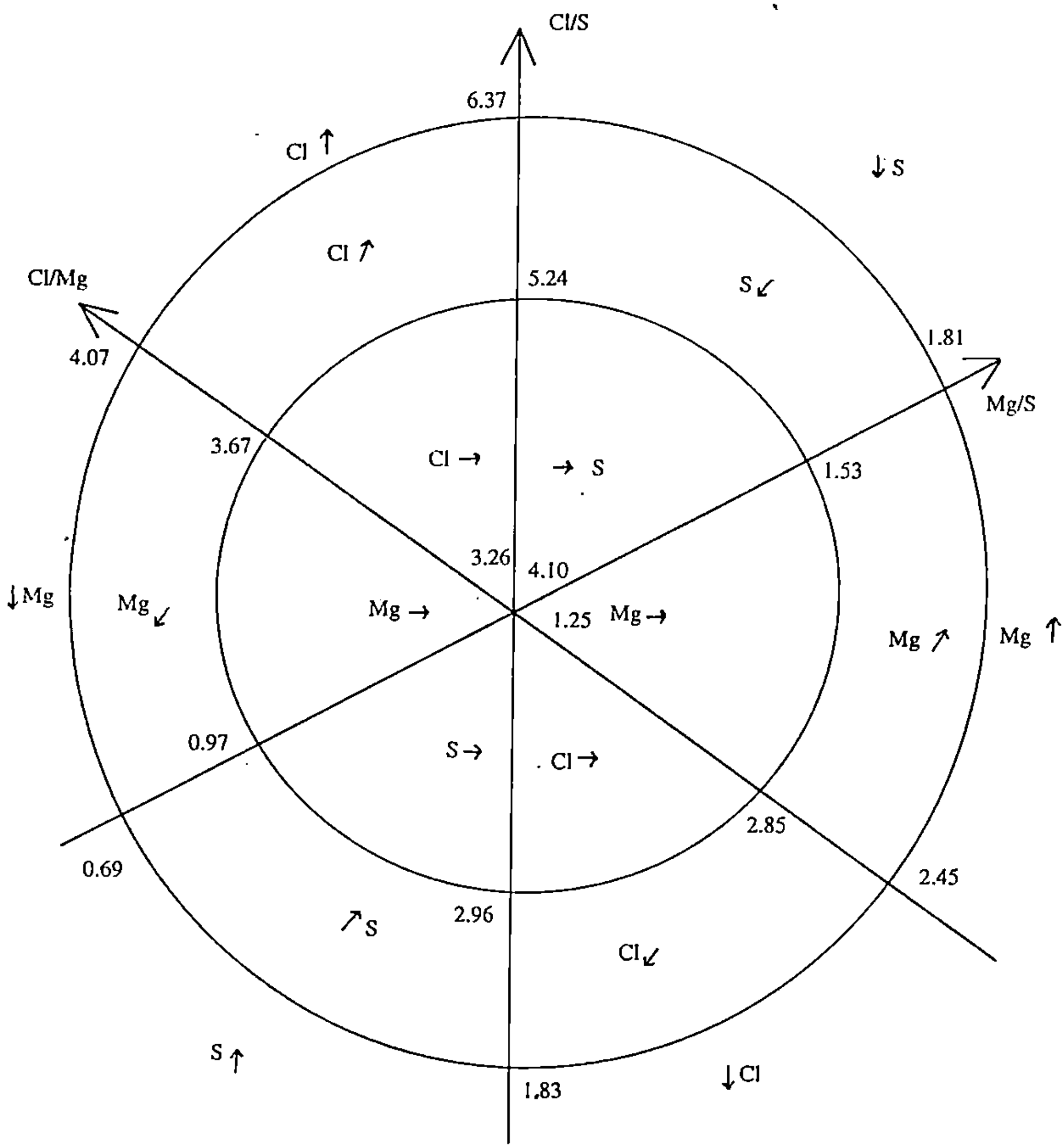

Fig. 2. DRIS chart for Cl, Mg and S in coconut

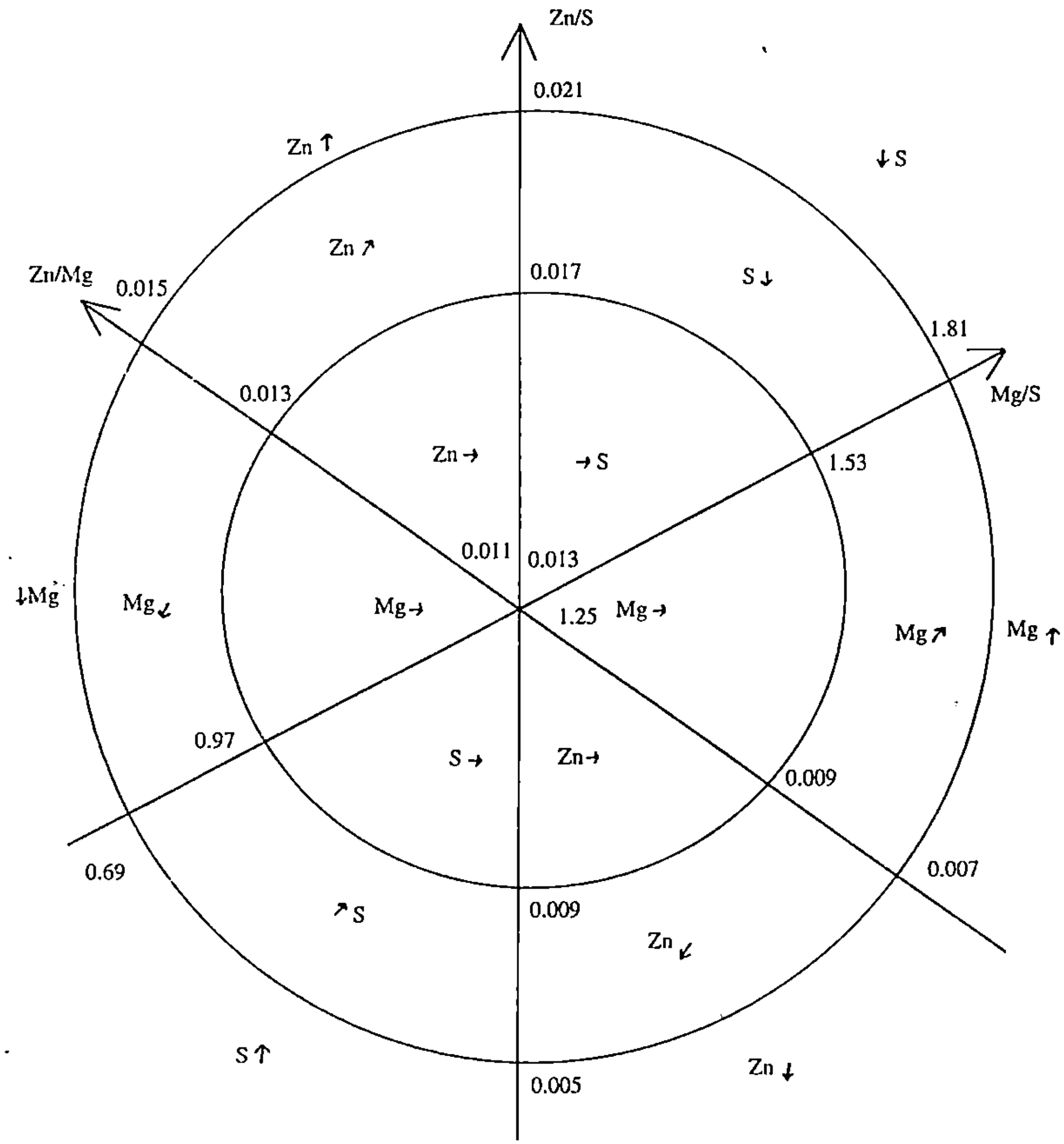

Fig.3. DRIS chart for Zn, Mg and S in coconut

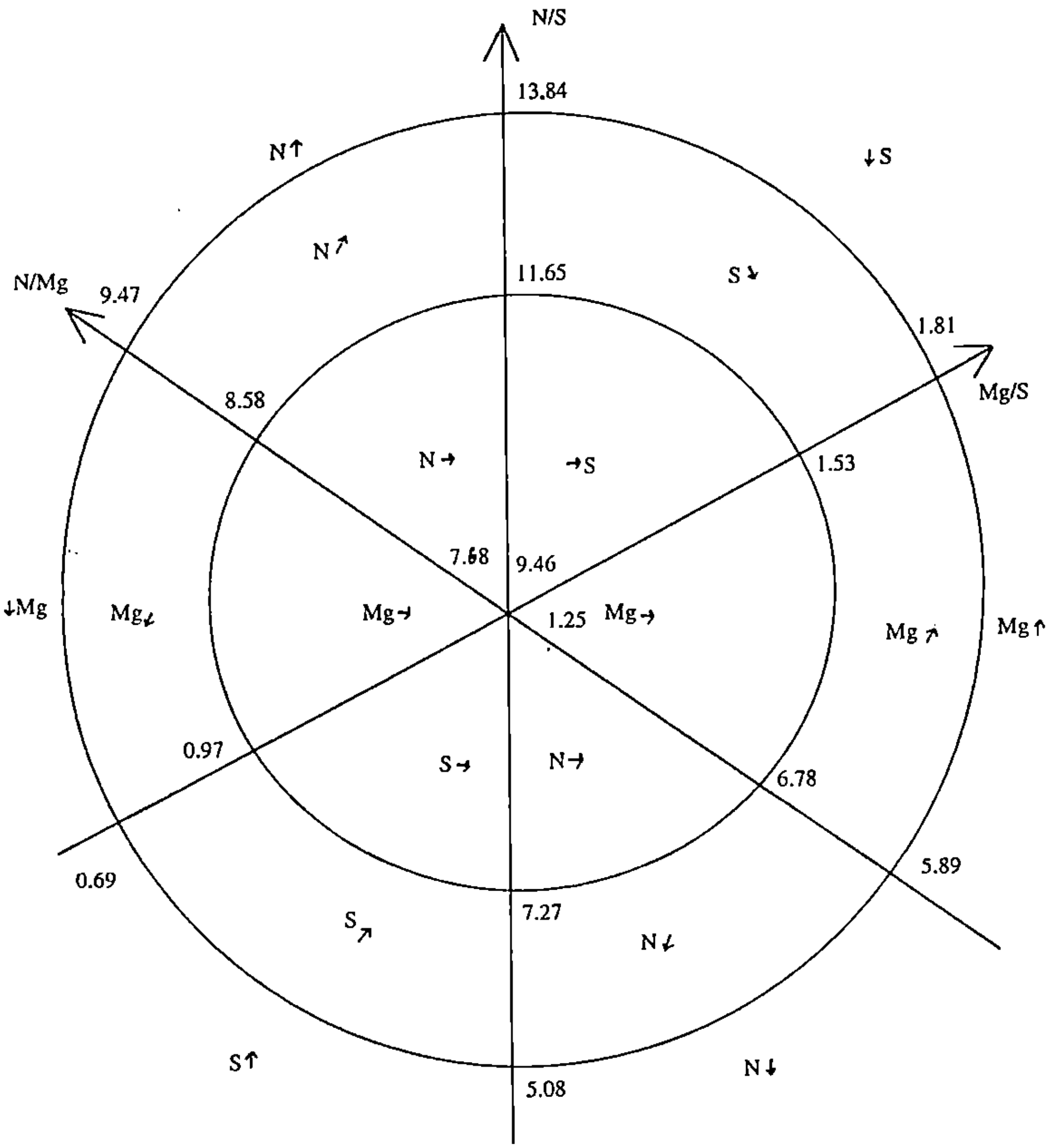

Fig. 4. DRIS chart for N, Mg and S in coconut

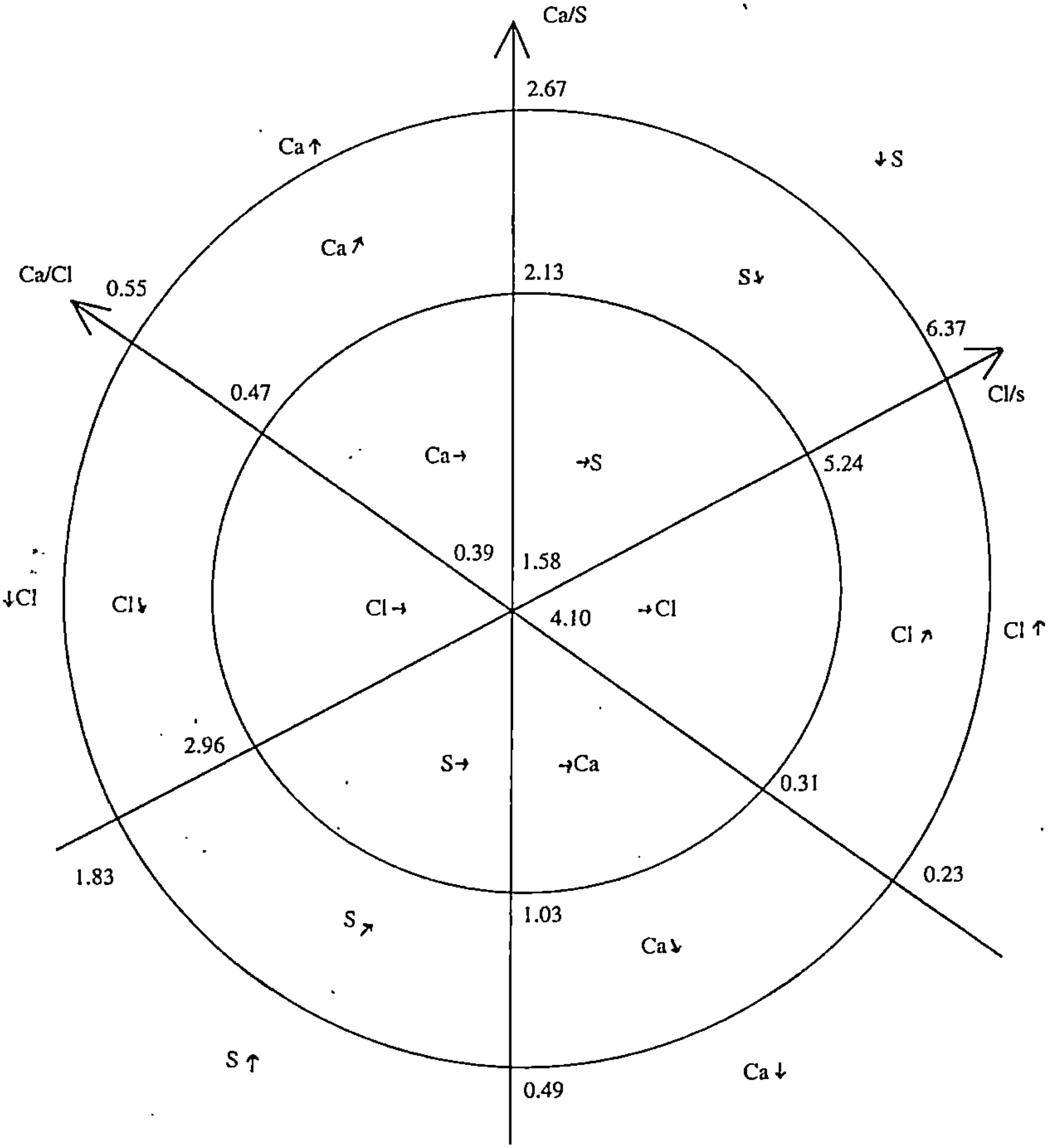

Fig. 5. DRIS chart for Ca, S and Cl in coconut

Table 7. DRIS indices for major and micronutrients and nutrient imbalance indices (NII) for coconut palms under different NPK treatments in relation to their yield

Treatmer	N	P	K	Ca	Mg	S	Cl	Fe	Zn	Mn	NII	Yield
N0P0K0	-17	-7	-24	11	13	3	3	-16	26	8	**128**	34.25
N0P0K1	-17	-11	0	-5	7	1	2	-2	10	15	**70**	55.15
N0P0K2	-18	-12	4	-6	-1	16	-5	-7	16	13	**98**	79.75
N0P1K0	-20	-3	-17	-3	7	4	-10	-9	32	19	**124**	13.05
N0P1K1	-20	0	-3	-12	3	7	-11	-7	31	12	**106**	46.35
N0P1K2	-26	-6	8	3	5	-2	-2	-4	16	8	**80**	49.15
N0P2K0	-20	6	-46	11	11	10	1	-1	3	24	**132**	14.55
N0P2K1	-27	0	-7	-3	0	5	-10	-4	30	16	**102**	60.5
N0P2K2	-16	1	1	-7	1	7	2	-3	9	5	**52**	82
N1P0K0	-9	-12	-38	-10	16	14	2	6	9	22	**138**	21.8
N1P0K1	-10	-9	-16	3	8	11	1	13	3	23	**98**	49.05
N1P0K2	-9	-12	7	-14	1	11	-8	-14	20	18	**114**	83.5
N1P1K0	8	10	-170	16	18	26	6	1	45	40	**340**	10.75
N1P1K1	-10	0	-34	11	11	11	-5	-4	6	14	**106**	75.75
N1P1K2	-12	-1	4	-11	4	14	-3	-5	3	7	**64**	95.85
N1P2K0	9	23	-168	32	36	28	-4	10	18	17	**374**	6.1
N1P2K1	-13	3	-34	-1	9	10	-2	1	11	16	**100**	46.7
N1P2K2	-16	5	-1	-11	4	7	-10	-8	23	8	**94**	78.35
N2P0K0	6	-2	-178	13	33	30	-2	-4	56	48	**372**	22.85
N2P0K1	-9	-14	-28	7	9	8	-10	-6	9	34	**134**	60.9
N2P0K2	-7	-13	6	-4	0	7	-1	-7	4	15	**64**	66.65
N2P1K0	2	-4	-93	28	16	-6	4	-3	10	46	**212**	3.8
N2P1K1	-5	-1	-19	6	9	13	-9	-8	6	7	**84**	74.35
N2P1K2	-10	-10	-3	6	-1	7	-4	-11	4	22	**78**	83.25
N2P2K0	21	16	-196	28	23	3	-8	-7	55	65	**422**	0.85
N2P2K1	-9	2	-39	14	9	5	3	-4	7	12	**104**	60.35
N2P2K2	-8	2	-2	-1	1	7	-7	-14	3	19	**64**	86.45

N0, N1, and N2 represent zero, 340 and 680 g N; P0, P1 and P2 represent zero, 225 and 450 g P2O5; K0, K1 and K2 represent zero, 450 and 900 g K2O per palm per year respectively indices for a given nutrient under different levels of application (keeping the level of application of the other nutrients constant) were compared, there was a clear indication of improving the index from a more negative value to a more positive value with increasing level of application of that nutrient. For example, when K index is compared among the three levels of applied K keeping the levels of N and P constant, the index was found to increase with increasing level of K application. This was also the case with the other two applied nutrients namely N and P. When yield was compared in relation to the DRIS index of a particular nutrient at varying levels of its application and keeping the level of application of the other two nutrients constant there was an improvement in yield with increasing values of DRIS index in the case of K. In the case of the other two nutrients namely, N and P, the change in yield was not, however, corresponding to the change in their indices.

The DRIS index only shows the degree of balance/imbalance of a particular nutrient. The overall condition of the palm with respect to its nutritional balance can be assessed by computing its nutrient imbalance index (NII). The nutrient imbalance index is the sum of the nutrient indices disregarding the sign. The data relating to NII based on ten nutrient indices for palms receiving various levels of NPK are given in Table 7. The correlation between NII and yield was found to be negative and significant at 1 per cent level (r^2 = 0.542). However, better relationship (R^2= 0.673) was obtained for a curvilinear quadratic equation. This relationship is presented in Fig. 6.

4.5. Comparison of DRIS norms based on different criteria

In order to examine the influence, if any, of the criterion used in dividing the population into low- and high-yielding subpopulations, two cut-off values were used and compared the resulting DRIS norms with those already developed. When a yield of 80 nuts per palm per year was used as the cut-off value to divide the population into low- and high-yield groups there were 614 palms coming under the low-yield group (< 80 nuts per palm per year) and 186 palms in the high-yield group (> 80 nuts per palm per year). It may be noted that the cut-off value i.e., 80 nuts per palm per year is very close to the value of high-yield group (85.9 nuts per palm per year) used already to separate the high yielding subpopulation for developing DRIS norms. DRIS norm for a nutrient or nutrient ratio being the mean value for the high yielding population, it is likely that the norms worked out already may not be different from that worked out using the cut-off value of 80 nuts per palm per year. Nevertheless, since the criterion for defining the low-yielding population is different (mean minus SD in the case of DRIS norms already developed and less than 80 nuts per palm per year in the other case), the magnitude and hence statistical

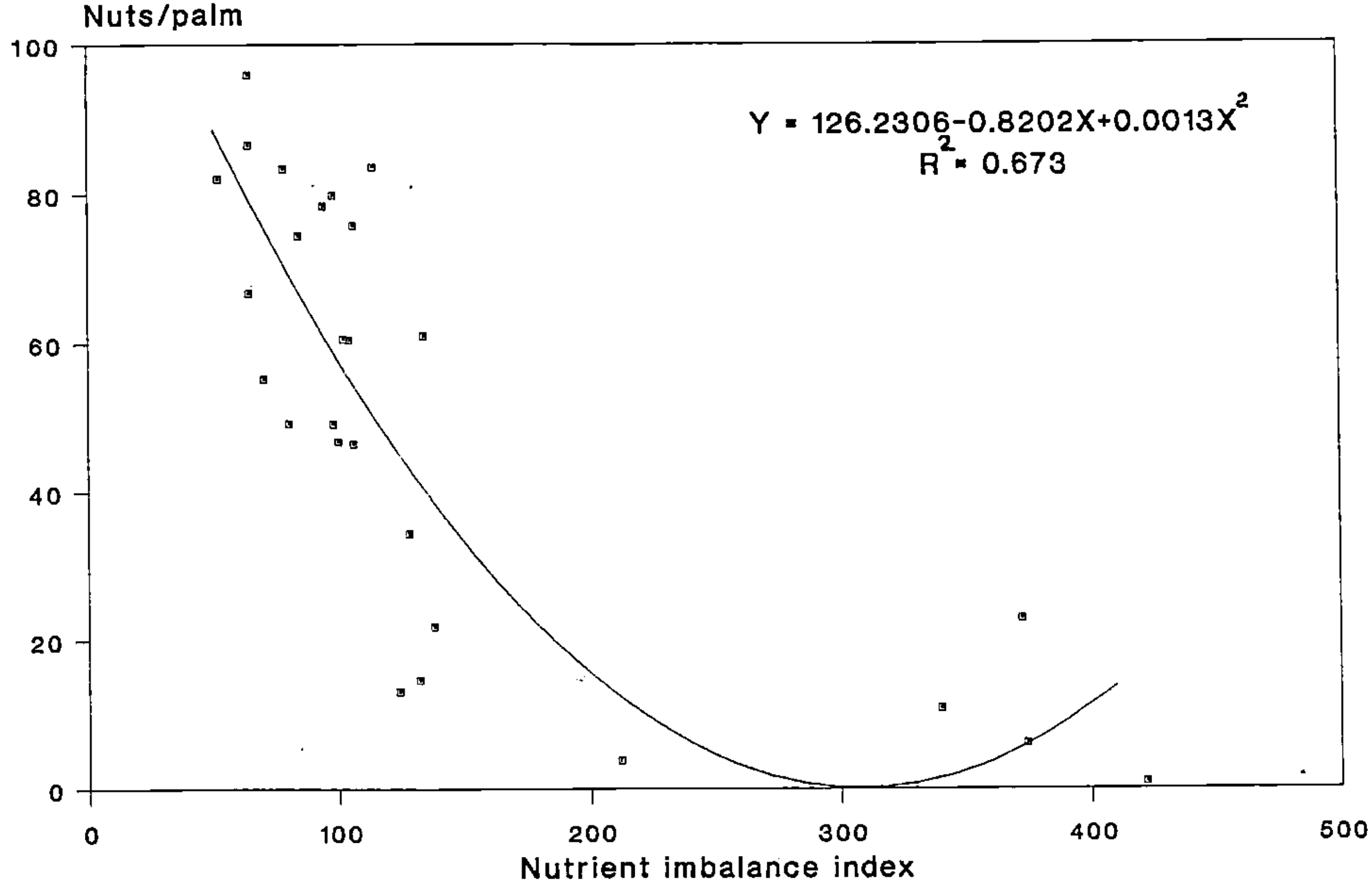

Fig.6 Relationship between nutrient imbalance index and yield in coconut

significance of the variance ratio between the low- and high-yield groups can be different. A cut-off value of 60 nuts per palm per year is also included for comparison. When 60 nuts per palm per year was used to divide the population, there were 428 palms in the low-yield group and 372 palms in the high-yield group.

The data relevant to the DRIS norms based on 80 nuts per palm per year as the cut-off value and the forms of expression whose variance ratios are statistically significant are given in Appendix 5. The selected DRIS norms and other relevant data are presented in Table 8. Based on this criterion, five nutrient elements and 35 nutrient ratios could be selected.

The data pertaining to the DRIS norms based on 60 nuts per palm per year as the cut-off value and the forms of expression whose variance ratios are statistically significant are given in Appendix 6. The selected DRIS norms and other data are presented in Table 9. Based on this criterion, four nutrient elements and 37 nutrient ratios could be selected.

4.6. Influence of soil type on DRIS norms

The total population was divided into two namely, palms growing on laterite soil (Pilicode + Mannuthy) and palms growing on red sandy loam soil (Balaramapuram). The total number of palms according to this grouping was 500

Table 8. DRIS norms for coconut palms using 80 nuts per palm per year as the yield cut-off value

Form of expression	Low yield group (A)			High yield group (B)			Variance ratio (SA/SB)
	Mean	Variance (SA)	CV (%)	Mean	Variance (SB)	CV (%)	
N	1.620	0.093	18.89	1.510	0.067	17.10	1.41
Ca	0.303	0.008	29.37	0.246	0.005	27.24	1.70
Mg	0.188	0.001	19.68	0.197	0.001	15.20	1.95
Cl	0.627	0.009	15.47	0.638	0.006	12.38	1.50
Zn	0.002	0.000	26.09	0.002	0.000	23.81	1.44
N/P	11.950	19.990	37.41	8.530	5.740	28.14	3.48
N/Mg	8.910	7.510	30.75	7.760	2.030	18.30	3.70
N/S	15.420	62.730	51.36	9.820	11.230	34.11	5.58
N/Cl	2.630	0.517	27.33	2.460	0.375	24.92	1.38
N/Fe	66.170	1279.200	54.05	56.670	418.290	36.10	3.06
P/K	0.121	0.003	43.80	0.162	0.005	42.59	1.73
P/Ca	0.519	0.043	39.88	0.814	0.079	34.52	1.85
P/Fe	6.020	13.500	60.96	7.050	9.430	43.55	1.43
P/Mn	7.460	10.750	43.97	9.660	15.210	40.37	1.41
K/Ca	4.610	3.350	39.69	5.430	5.340	42.54	1.60
K/S	12.680	36.480	47.63	8.660	19.670	51.27	1.85
Ca/Mg	1.670	0.212	27.54	1.290	0.146	29.61	1.45
Ca/S	2.920	1.820	46.23	1.720	0.805	52.15	2.26
Ca/Cl	0.507	0.033	35.70	0.405	0.019	34.07	1.72
Ca/Fe	12.020	26.980	43.17	9.180	10.420	35.18	2.59
Ca/Zn	145.460	4092.000	44.12	123.600	2136.600	37.39	1.92
Ca/Mn	15.360	46.440	44.34	12.400	14.160	30.32	3.28
Mg/P	1.380	0.202	32.61	1.140	0.117	30.00	1.73
Mg/S	1.760	0.509	40.56	1.300	0.223	36.31	2.28
Mg/Fe	7.680	16.700	53.25	7.420	7.680	37.33	2.17
S/P	0.871	0.114	38.69	0.936	0.075	29.27	1.51
Cl/P	4.690	2.330	32.62	3.730	1.720	35.12	1.36
Cl/Mg	3.480	0.879	26.93	3.290	0.415	19.45	2.12
Cl/S	6.060	7.530	45.21	4.300	3.300	42.32	2.28
Cl/Fe	25.400	146.400	47.60	23.850	76.030	36.56	1.93
Fe/S	0.279	0.021	51.61	0.200	0.011	53.00	1.83
Zn/N	0.002	0.010*	33.33	0.002	0.001*	26.67	1.42
Zn/P	0.017	0.490*	41.17	0.013	0.250*	36.15	2.38
Zn/Mg	0.013	0.250*	38.46	0.011	0.090*	27.27	2.74
Zn/S	0.023	1.690*	56.52	0.015	0.490*	46.00	3.26
Zn/Cl	0.004	0.010*	36.84	0.004	0.010*	31.43	1.64
Zn/Fe	0.092	0.002	47.83	0.081	0.001	44.44	1.47
Mn/Mg	0.124	0.003	44.35	0.112	0.002	39.28	1.58
Mn/S	0.208	0.011	50.00	0.145	0.006	53.10	1.81
Mn/Fe	0.917	0.334	63.03	0.801	0.133	45.44	2.52

CV : Coefficient of variation

* : $X 10^{-4}$

Table 9. DRIS norms for coconut palm using 60 nuts per palm per year as yield cut-off valı

Form of expression	Low Yield Group(A) Mean	Variance (SA)	CV (%)	High Yield Group(B) Mean	Variance (SB)	CV (%)	Variance ratio (SA/SB)
N	1.640	0.100	19.27	1.520	0.071	17.57	1.40
P	0.141	0.002	28.37	0.174	0.002	28.16	1.55
Mg	0.186	0.002	20.97	0.196	0.001	15.82	1.52
S	0.117	0.003	43.59	0.163	0.005	42.33	1.85
N/P	12.730	23.060	37.71	9.350	7.720	29.73	2.99
N/Mg	9.260	8.740	31.97	7.930	2.900	21.44	3.01
N/S	17.010	72.280	49.85	10.790	17.440	38.74	4.15
N/Cl	2.730	0.592	28.21	2.430	0.322	23.33	1.84
P/K	0.113	0.002	37.17	0.152	0.005	46.05	2.81
P/Ca	0.483	0.029	35.61	0.707	0.082	40.45	2.78
P/S	1.340	0.223	35.22	1.180	0.169	34.83	1.32
P/Cl	0.233	0.006	33.05	0.278	0.009	33.09	1.42
P/Fe	5.430	9.850	57.83	7.220	14.370	52.49	1.46
P/Zn	68.520	798.060	41.23	81.790	1092.500	40.40	1.37
P/Mn	7.480	10.400	43.18	8.540	14.630	44.85	1.41
K/Fe	49.680	456.700	43.02	51.830	689.500	50.69	1.51
K/Zn	644.500	68169.000	40.53	589.090	49943.000	37.88	1.36
Ca/Cl	0.518	0.036	36.29	0.431	0.022	34.34	1.62
Ca/Zn	151.670	4407.700	43.68	124.810	2345.800	38.80	1.88
Ca/Mn	16.210	49.340	43.31	12.580	20.020	35.53	2.46
Mg/P	1.410	0.212	32.70	1.205	0.143	31.40	1.48
Mg/K	0.149	0.002	32.89	0.168	0.003	34.52	1.41
Mg/Ca	0.628	0.026	25.50	0.779	0.048	27.98	1.87
Mg/S	1.830	0.522	39.51	1.390	0.307	39.93	1.70
Mg/Mn	10.060	20.500	45.02	9.650	15.140	40.31	1.35
S/K	0.094	0.002	50.00	0.143	0.007	58.04	3.13
S/Ca	0.399	0.039	50.51	0.659	0.114	51.28	2.93
S/Mn	6.180	11.560	55.01	7.850	16.630	51.97	1.44
Cl/K	0.492	0.016	25.81	0.540	0.024	28.89	1.52
Cl/Mg	3.490	0.968	28.19	3.350	0.494	20.99	1.96
Cl/S	6.320	7.940	44.62	4.670	4.340	44.54	1.83
Fe/N	0.019	0.810*	46.84	0.019	0.640*	40.00	1.37
Fe/S	0.301	0.021	47.84	0.205	0.013	55.61	1.60
Fe/Cl	0.050	3.600*	38.00	0.044	2.560*	36.82	1.47
Fe/Mn	1.630	0.738	52.70	1.360	0.508	52.43	1.45
Zn/Mg	0.013	0.250*	40.00	0.012	0.160*	34.17	1.60
Zn/S	0.023	1.700*	56.52	0.017	0.810*	53.52	2.08
Zn/Cl	0.004	0.010*	37.84	0.004	0.010*	32.43	1.42
Zn/Mn	0.119	0.003	45.38	0.111	0.002	42.34	1.32
Mn/N	0.013	0.360*	42.31	0.016	0.340*	40.13	1.33
Mn/K	0.017	0.640*	48.23	0.020	1.000*	49.50	1.49

CV : Coefficient of variation

* : $X\ 10^{-4}$

for the laterite (Ultisol) soil and 300 for the red sandy loam (Alfisol) soil. The method of Davee et al. (1986) was used to divide each of these populations into low and high yielding groups. In the case of laterite soil, the low and high yielding subpopulations consisted of 85 and 75 palms respectively while for red sandy loam, the corresponding figures were 62 and 41 respectively.

A total number of 45 forms of expressions which included five nutrients and 40 nutrient ratios, were found to give significant variance ratios between the low- and high-yield groups in the laterite soil group (Appendix 7). Of these, only 27 ratios were selected. The selected forms of expression and their relevant data are given in Table 10.

A total number of 48 forms of expressions were found to give significant variance ratios between the low- and high-yield groups in red sandy loam soil group (Appendix 8). Of these only two nutrients and 34 ratios were selected. The selected forms of expression and their relevant data are given in Table 11.

A comparison of the DRIS norms developed for the total population (Table 5), for laterite soil alone (Table 10) and for red sandy loam soil alone (Table 11) showed wide variations in the forms of expression that could be selected for the three categories. There was not a single nutrient which could be selected uniformly in all the

Table 10. DRIS norms for coconut palm growing on laterite soil

Form of expression	Low yield group(A)			High yield group(B)			Variance ratio (SA/SB)
	Mean	Variance (SA)	CV (%)	Mean	Variance (SB)	CV (%)	
N	1.590	0.168	25.79	1.350	0.080	20.74	2.09
K	1.450	0.127	24.83	1.300	0.036	14.62	3.51
Mg	0.184	0.002	21.20	0.179	0.001	16.20	1.77
S	0.120	0.003	45.00	0.122	0.001	30.33	2.10
Zn	0.002	0.010*	30.00	0.002	0.001*	22.00	1.82
N/P	11.260	21.810	41.47	10.090	10.330	31.83	2.11
N/Mg	9.210	15.310	42.45	7.680	3.410	24.06	4.49
N/S	17.520	119.030	62.20	11.780	12.390	29.87	9.61
N/Cl	2.680	0.768	32.83	2.200	0.428	29.71	1.80
N/Fe	49.800	451.800	42.69	41.050	142.540	29.08	3.17
N/Mn	98.670	1697.900	41.77	67.800	953.200	45.50	1.78
K/N	0.990	0.177	42.42	1.010	0.083	28.43	2.14
K/Mg	8.230	6.880	31.83	7.520	4.140	27.07	1.66
K/S	14.400	39.460	43.61	11.620	15.520	33.92	2.54
K/Cl	2.420	0.483	28.72	2.100	0.178	20.13	2.71
K/Zn	751.750	127351.000	47.47	679.700	38131.000	28.73	3.34
K/Mn	94.630	2472.000	52.54	67.550	1149.700	50.20	2.15
Ca/P	2.030	0.359	29.56	2.160	0.740	39.76	2.05
Ca/S	3.030	2.220	49.17	2.520	0.850	36.70	2.60
Ca/Mn	18.270	59.120	42.03	13.550	19.470	32.55	3.04
Mg/P	1.260	0.130	28.65	1.360	0.460	33.90	1.63
Mg/S	1.840	0.708	45.71	1.590	0.271	32.67	2.61
Mg/Mn	11.760	27.560	44.64	9.010	14.540	42.32	1.90
S/P	0.766	0.056	31.33	0.910	0.099	34.67	1.75
Cl/Mg	3.500	1.180	31.14	3.590	0.480	19.37	2.45
Cl/S	6.330	9.530	48.82	5.590	3.140	31.70	3.03
Zn/Mg	0.013	0.250*	39.23	0.012	0.090*	25.22	2.99
Zn/S	0.023	1.960*	60.86	0.018	0.490*	37.40	4.55
Zn/Cl	0.004	0.010*	30.00	0.003	0.010*	27.30	1.60
Zn/Fe	0.067	0.001	38.80	0.062	4.000*	32.40	1.81
Mn/P	0.126	0.003	46.03	0.173	0.007	48.80	2.17
Mn/S	0.090	0.015	63.60	0.202	0.008	43.28	1.93

CV : Coefficient of variation

* : $X 10^{-4}$

Table 11. DRIS norms for coconut palm growing on red sandy loam soil at Balaramapuram

Form of expression	Low Yield Group(A)			High Yield Group(B)			Variance ratio (SA/SB)
	Mean	Variance (SA)	CV (%)	Mean	Variance (SB)	CV (%)	
K	1.200	0.035	15.50	1.330	0.162	30.23	4.68
Ca	0.320	0.005	22.50	0.213	0.002	20.66	2.73
N/P	12.160	13.730	30.51	7.360	1.007	13.64	13.63
N/S	11.660	9.030	25.73	8.250	3.390	22.31	2.66
N/Fe	101.800	1384.200	36.54	68.640	462.300	31.30	2.99
P/K	0.136	0.001	24.26	0.175	0.006	42.40	5.03
K/N	0.670	0.016	19.10	0.930	0.147	41.22	9.00
K/Ca	3.970	1.100	26.45	6.600	8.070	43.05	7.32
K/S	7.690	4.720	28.22	7.750	14.250	48.70	3.02
K/Cl	1.890	0.117	18.10	2.090	0.399	30.21	3.42
K/Zn	603.400	22035.500	24.59	664.800	66679.900	38.84	3.03
K/Mn	53.570	232.170	28.45	79.960	1853.400	53.84	7.98
Ca/N	0.175	0.002	23.43	0.146	0.001	20.04	1.98
Ca/P	2.160	0.969	45.60	1.070	0.051	21.16	19.07
Ca/Mg	1.550	0.085	18.77	1.030	0.028	16.32	2.99
Ca/S	2.020	0.392	30.99	1.180	0.064	21.44	6.16
Ca/Fe	17.470	42.280	37.21	9.800	10.910	33.70	3.88
Ca/Zn	162.310	3924.600	38.60	106.510	988.000	29.51	3.97
Ca/Mn	14.150	24.260	34.84	11.940	10.570	27.22	2.30
Mg/P	1.370	0.222	34.31	1.030	0.024	15.14	9.16
Mg/S	1.310	0.111	25.50	1.150	0.043	18.19	2.54
Mg/Fe	11.330	16.000	35.30	9.510	6.220	26.22	2.57
S/P	1.120	0.242	43.75	0.924	0.041	22.00	5.85
S/Fe	9.290	17.980	45.64	8.340	3.270	21.69	5.50
Cl/N	0.350	0.002	13.43	0.440	0.007	19.49	3.27
Cl/P	4.260	1.660	30.28	3.200	0.409	20.01	4.08
Cl/Ca	2.120	0.220	22.17	3.080	0.413	20.86	1.87
Cl/S	4.130	1.430	28.81	3.570	0.780	24.74	1.84
Cl/Fe	35.510	144.820	33.88	29.410	70.390	28.53	2.06
Cl/Mn	28.530	47.490	24.15	36.810	160.080	34.35	3.37
Fe/P	0.132	0.003	49.16	0.115	0.001	28.52	3.18
Fe/K	0.017	0.360*	35.29	0.019	0.810*	45.69	2.10
Fe/Mn	0.880	0.109	37.50	1.310	0.194	33.68	1.78
Zn/N	0.001	0.001*	25.00	0.002	0.080*	33.33	2.45
Mn/P	0.156	0.003	34.62	0.095	0.001	34.32	2.75
Mn/Zn	12.060	19.720	36.81	9.360	9.550	33.05	2.07

CV : Coefficient of variation

* : $\times 10^{-4}$

three categories, although there were cases of a nutrient being selected for two of the three categories. For example, variance ratio of K was significant for coconut stands on laterite and red sandy loam soils (Tables 10 and 11) but when the pooled population was considered it was not significant (Table 5). Similarly, variance ratio of Ca was significant for the pooled population and also for palms growing on red sandy loam soil but not for those growing on laterite soil. Such a discrepancy was also found for several nutrient ratios. Nevertheless, in contrast to the individual nutrients, there were cases of nutrient ratios being selected uniformly in all the three cases. These ratios were N/P, N/S, N/Fe, K/N, K/Cl, K/Zn, K/Mn, Ca/S, Ca/Mn and Mg/S. These apart, the other ratios were either selected under one category or in any two categories but not in all the three categories.

4.7. Influence of location on DRIS norms

The palms growing on the same soil type were selected from two different locations namely Pilicode and Mannuthy to examine whether there is location-specific variation in DRIS norms. The total number of palms selected from Pilicode was 330 and that from Mannuthy was 170. The method of Davee et al. (1986) was used to discriminate the low- and high-yield groups. In the case of Pilicode, the low- and high-yielding subpopulations were 58 and 49 palms respectively while for Mannuthy, the corresponding figures were 13 and 30 respectively.

A total of 50 forms of expression which included four nutrients and 46 nutrient ratios, were found to give significant variance ratios between the low- and high-yielding groups at Pilicode (Appendix 9). Of these, only 30 ratios were selected. The selected forms of expression and their relevant data are given in Table 12. In the case of Mannuthy population, two nutrient elements and twenty nutrient ratios yielded significant variance ratios (Appendix 10). Out of the 20 nutrient ratios, 18 were selected for DRIS norms. The selected forms of expression and their relevant data are given in Table 13.

A comparison of the DRIS norms developed for the total population (Table 5), for Pilicode (Table 12) and for Mannuthy (Table 13) showed wide variations in the forms of expression that could be selected. Here again, not a single nutrient could be selected uniformly in all the three categories, although P and Mg could be selected for the pooled population and for the Pilicode population. Such discrepancies were found for several nutrient ratios also. In contrast to this, nutrient ratios viz., P/S, K/N, Cl/Mg and Mn/S could be uniformly selected in all the three cases. The other nutrient ratios were either selected under one category or in any two categories but not in all the three cases.

Further, a comparison of DRIS norms developed for the laterite soil (Table 10), for Pilicode (Table 12) and

Table 12. DRIS norms for coconut palm growing on laterite soil at Piliocde

Form of expression	Low Yield Group(A)			High Yield Group(B)			Variance ratio
	Mean	Variance (SA)	CV (%)	Mean	Variance (SB)	CV (%)	(SA/SB)
P	0.127	0.001	18.11	0.118	1.690*	11.02	3.11
Mg	0.171	0.002	25.15	0.167	0.001	17.37	2.20
S	0.065	0.810*	13.85	0.109	0.001	21.10	5.23
Fe	0.031	0.640*	25.81	0.028	0.250*	17.86	2.14
N/P	15.340	13.650	24.05	11.000	6.950	23.97	1.96
N/Mg	11.770	14.210	32.03	7.870	5.170	28.91	2.75
N/Zn	817.620	46307.000	26.33	648.980	27034.000	25.34	1.72
P/K	0.120	0.001	28.33	0.089	2.890*	18.99	3.99
P/S	1.980	0.172	20.91	1.120	0.047	19.43	3.65
P/Cl	0.210	0.003	24.76	0.196	0.001	18.16	2.15
K/N	0.600	0.020	23.33	1.110	0.074	24.60	3.81
K/Ca	4.000	2.030	35.50	5.400	5.690	44.13	2.81
Ca/N	0.160	0.002	30.63	0.230	0.006	34.48	2.60
Ca/Mn	16.560	43.450	39.79	12.970	11.930	26.64	3.64
Mg/P	1.390	0.240	35.25	1.440	0.091	20.87	2.66
Mg/K	0.160	0.004	37.50	0.127	0.001	27.00	3.09
Mg/Ca	0.590	0.019	23.22	0.630	0.037	30.30	1.96
Mg/S	2.660	0.452	25.26	1.600	0.170	25.76	2.65
S/N	0.035	0.640*	22.86	0.089	7.290*	30.23	12.58
S/Ca	0.232	0.004	27.59	0.410	0.014	29.22	3.52
S/Cl	0.108	0.001	24.07	0.182	0.002	25.60	3.32
S/Fe	2.220	0.223	21.31	4.036	0.884	23.30	3.96
S/Zn	28.400	58.450	26.94	56.780	359.100	33.37	6.14
Cl/N	0.340	0.007	24.41	0.500	0.020	28.10	2.95
Cl/K	0.589	0.024	26.32	0.458	0.007	18.56	3.34
Cl/Mg	3.900	1.510	31.54	3.760	0.668	21.76	2.25
Fe/N	0.017	0.160*	23.53	0.023	0.640*	32.61	2.86
Fe/P	0.250	0.006	31.20	0.236	0.002	18.39	3.23
Fe/K	0.029	1.210*	37.93	0.021	0.160*	19.05	7.44
Fe/Mg	0.189	0.004	34.39	0.170	0.002	25.77	2.17
Zn/K	0.002	0.010*	30.43	0.002	0.004*	26.67	3.26
Zn/Mg	0.020	1.000*	50.00	0.010	0.003	25.00	2.48
Mn/N	0.011	0.160*	36.36	0.019	0.490*	39.57	3.48
Mn/S	0.308	0.012	35.06	0.213	0.005	33.40	2.31

CV : Coefficient of variation

* : $X\ 10^{-4}$

Table 13. DRIS norms for coconut palms growing on laterite soil at Mannuthy

Form of expression	Low Yield Group(A)			High Yield Group(B)			Variance ratio
	Mean	Variance (SA)	CV (%)	Mean	Variance (SB)	CV (%)	(SA/SB)
K	1.610	0.123	21.74	1.230	0.033	14.72	3.74
Mn	0.015	0.36	40.00	0.022	1.00(	44.10	3.04
P/S	1.070	0.056	22.15	1.480	0.433	44.43	7.69
K/N	1.260	0.153	31.11	0.862	0.052	26.42	2.96
K/Ca	7.270	8.880	40.99	4.870	2.790	34.31	3.18
K/Mg	9.180	10.300	34.97	6.600	1.970	21.28	5.22
K/S	13.290	51.180	53.70	10.530	18.150	40.45	2.82
K/Cl	2.550	0.210	18.04	1.890	0.082	15.11	2.59
K/Zn	903.600	136592.000	40.90	628.900	43718.000	33.25	3.12
Ca/P	1.750	0.203	25.71	1.710	0.700	48.93	3.45
Mg/P	1.330	0.088	22.26	1.210	0.309	45.80	3.53
Cl/Mg	3.630	1.420	32.78	3.490	0.310	15.99	4.57
Zn/N	0.002	0.01	56.25	0.002	0.01	33.33	3.36
Mn/P	0.102	0.001	27.45	0.141	0.009	68.90	12.15
Mn/K	0.010	0.36	59.60	0.019	1.00	53.09	3.05
Mn/Ca	0.060	1.69	21.67	0.083	0.001	39.40	6.31
Mn/S	0.109	0.001	33.94	0.189	0.009	52.59	6.99
Mn/Fe	0.359	0.013	31.50	0.528	0.065	48.16	5.11
Mn/Mg	0.079	0.001	31.65	0.117	0.002	39.32	3.45
Mn/Zn	7.690	6.070	31.99	11.090	24.670	44.75	4.06

CV : Coefficient of variation

* : $X 10^{-4}$

Mannuthy (Table 13) also showed that wide variations existed in the forms of expression that could discriminate between low- and high-yielding subpopulations in these categories. As in the previous case, there was not a single nutrient which could be selected in all the three categories. Variance ratios of Mg and S were found to be significant in laterite and Pilicode populations while foliar K level was found to discriminate between the low- and high- yield groups in laterite and Mannuthy population. Similar discrepancy was also found for several nutrient ratios. Nevertheless, the following nutrient ratios viz., K/N, Mg/P, Cl/Mg and Mn/S were uniformly selected in all the three cases. The other ratios were either selected under one category or in any two categories but not in all.

4.8. Comparison of DRIS with critical level approach

DRIS indices were worked out for 27 palms receiving varying levels of N, P and K fertilizers. Foliar nutrient composition of these palms are given in Table 14 and the order of requirement of the ten nutrients based on their indices and a comparison of these with the critical level concept are given in Table 15. Palms under N0P0K0 treatment showed the lowest index for K followed by N, Fe and P. Going by the critical level concept, these palms are deficient in K and N but not P. The palms receiving N0P0K2 treatment showed the lowest index for N. The

Table 14.Foliar nutrient composition of palms recieving different NPK fertilizer treatments

Treatment	N	P	K	Ca	Mg	S	Cl	Fe	Zn	Mn
N0P0K0	1.03	0.15	0.65	0.28	0.22	0.16	0.60	157	30	213
N0P0K1	1.07	0.14	1.24	0.21	0.20	0.17	0.66	263	24	287
N0P0K2	1.14	0.16	1.47	0.22	0.20	0.27	0.60	226	29	280
N0P1K0	1.09	0.19	0.84	0.23	0.23	0.19	0.52	215	37	313
N0P1K1	1.06	0.20	1.16	0.18	0.21	0.21	0.52	216	36	250
N0P1K2	0.98	0.17	1.63	0.27	0.22	0.16	0.62	238	29	240
N0P2K0	1.11	0.23	0.52	0.31	0.24	0.22	0.63	266	21	349
N0P2K1	1.02	0.21	1.11	0.24	0.21	0.21	0.56	257	38	307
N0P2K2	1.16	0.21	1.35	0.21	0.21	0.21	0.67	246	25	227
N1P0K0	1.19	0.14	0.51	0.17	0.23	0.21	0.57	231	22	315
N1P0K1	1.25	0.16	0.87	0.26	0.23	0.23	0.63	186	19	344
N1P0K2	1.30	0.15	1.51	0.17	0.20	0.22	0.54	180	30	296
N1P1K0	1.33	0.18	0.17	0.24	0.19	0.21	0.49	199	29	308
N1P1K1	1.26	0.19	0.58	0.30	0.23	0.23	0.54	230	21	262
N1P1K2	1.19	0.19	1.40	0.18	0.21	0.25	0.58	230	20	222
N1P2K0	1.37	0.23	0.17	0.31	0.24	0.22	0.42	243	19	204
N1P2K1	1.26	0.22	0.63	0.25	0.24	0.23	0.62	253	26	328
N1P2K2	1.19	0.23	1.27	0.19	0.22	0.21	0.54	217	33	242
N2P0K0	1.40	0.16	0.18	0.24	0.25	0.24	0.47	200	35	366
N2P0K1	1.35	0.15	0.68	0.29	0.24	0.21	0.53	230	24	415
N2P0K2	1.37	0.15	1.53	0.22	0.20	0.21	0.64	215	22	292
N2P1K0	1.47	0.16	0.30	0.37	0.22	0.13	0.58	232	21	412
N2P1K1	1.33	0.18	0.72	0.26	0.22	0.23	0.49	191	21	214
N2P1K2	1.46	0.18	1.36	0.33	0.23	0.24	0.67	224	25	384
N2P2K0	1.75	0.23	0.17	0.31	0.22	0.13	0.44	194	34	444
N2P2K1	1.39	0.22	0.53	0.35	0.24	0.20	0.69	314	24	280
N2P2K2	1.46	0.23	1.29	0.26	0.23	0.23	0.60	196	23	342

Note: Concentrations of N, P, K, Ca, Mg, S and Cl expressed in percentage and those of Fe, Zn and Mn in ppm.

Table 15. Comparison of DRIS and critical level approaches for diagnosing nutrient disorders in coconut palm

Treatment	Order of nutrient requirement based on DRIS	Deficient nutrient identified through critical level approach
N0P0K0	K> N> Fe> P> S= Cl> Mn> Ca> Mg> Zn	N, K, Ca, Mg
N0P0K1	N> P> Ca> Fe> K> S> Cl> Mg> Zn> Mn	N, Ca, Mg
N0P0K2	N> P> Fe> Ca> Cl> Mg> K> Mn> S= Zn	N, Ca, Mg
N0P1K0	N> K> Cl> Fe> P= Ca> S> Mg> Mn> Zn	N, Ca, Mg
N0P1K1	N> Ca> Cl> Fe> K> P> Mg> S> Mn> Zn	N, Ca, Mg
N0P1K2	N> P> Fe> S= Cl> Ca> Mg> K= Mn> Zn	N, Ca, Mg
N0P2K0	K> N> Fe> Cl> Zn> P> S> Mg= Ca> Mn	N, K
N0P2K1	N> Cl> K> Fe> Ca> P>= Mg> S> Mn> Zn	N, Ca, Mg
N0P2K2	N> Ca> Fe> P= K= Mg> Cl> Mn> S> Zn	N, Ca, Mg
N1P0K0	K> P> Ca> N> Cl> Fe> Zn> S> Mg> Mn	N, K, Ca, Mg
N1P0K1	K> N> P> Cl> Ca= Zn> Mg> S> Fe> Mn	N, Ca,Mg
N1P0K2	Ca= Fe> P> N> Cl> Mg> K> S> Mn> Zn	N, Ca, Mg
N1P1K0	K> Fe> Cl> N> P> Ca> Mg> S> Mn> Zn	N, K, Ca, Mg
N1P1K1	K> N> Cl> Fe> P> Zn> Ca= Mg= S> Mn	N, K, Mg
N1P1K2	N> Ca> Fe> Cl> P> K= Mg> Zn> Mn> S	N, Ca, Mg
N1P2K0	K> Cl> N> Fe> Mn> Zn> P> S> Ca> Mg	N, K
N1P2K1	K> N> Cl> Ca> Fe> P> Mg> S> Zn> Mn	N, K, Ca, Mg
N1P2K2	N> Ca> Cl> Fe> K> Mg> P> S> Mn> Zn	N, Ca
N2P0K0	K> Fe> P>= Cl> N> Ca> S> Mg> Mn> Zn	N, K, Ca
N2P0K1	K> P> Cl> N> Fe> Ca> S> MG> Zn> Mn	N, K, Ca
N2P0K2	P> N= Fe> Ca> Cl> Mg> Zn> K> S> Mn	N, Ca, Mg
N2P1K0	K> S> P> Fe> N> Cl> Zn> Mg> Ca> Mn	N, K, Mg
N2P1K1	K> Cl> Fe> N> P> Ca= Zn> MN> Mg> S	N, K, Ca, Mg
N2P1K2	Fe> N= P> Cl> K> Mg> Zn> Ca> S> Mn	N, Mg
N2P2K0	K> Cl> Fe> S> P> N> Mg> Ca> Zn> Mn	N, K, Mg
N2P2K1	K> N> Fe> P> Cl> S> Zn> Mg> Mn> Ca	N, K
N2P2K2	Fe> N> Cl> K> Ca> Mg> P> Zn> S> Mn	N, Ca, Mg

indices for all other nutrients were much higher than for N. The nutrient requirement based on these indices followed the order N > P > Fe > Ca and then the others. Rating the foliar nutrient levels based on critical values, three nutrients namely, N, Ca and Mg were found to be deficient. The palms under N0P0K2 treatment showed the lowest index for N, those under N0P2K0, N1P0K0 and N2P0K0 treatments yielded the lowest indices for K and those under N2P2K2 gave the lowest value for Fe. The DRIS indices for the other nutrients were higher than for these nutrients in the respective treatments. Based on the critical level approach, palms receiving N1P0K0 were deficient in K, N, Ca, and Mg; those under N2P0K0 were deficient in K, N and Ca; those under N0P0K2 were deficient in N, Ca and Mg and those under N2P2K2 treatment were deficient in N, Ca, and Mg.

4.9. Relationship between DRIS index and foliar nutrient level

The relationships between DRIS indices and foliar levels of the respective nutrients are given in Table 24. Barring Fe, significant and positive correlations were obtained between DRIS indices and nutrient concentrations. Among these, the r values for Cl and Mg were comparatively smaller (significant at 5% level) than for others (significant at 1% level). In the case of K, an exponential equation fitted better than the linear equation. The R^2 value for this relationship was 0.989.

The relationship is presented in Fig. 7. The scatter diagrams showing the linear relationships yielding high r values for the other nutrients (N, P, Ca, S, Zn and Mn) are presented in Figs. 8 to 13.

4.10. Relationships between yield and foliar nutrient levels

The population of palms at each location was grouped into 24 yield classes. The class means for nutrients and nutrient ratios were correlated with their yield means. In addition, correlations were also worked out for laterite soil (combining Pilicode and Mannuthy populations) and also for the total population, i.e., pooling the three locations together.

The correlations between foliar nutrient levels and yield are given in Table 16. Foliar N level was negatively correlated with yield in all the locations excepting in Mannuthy where the r value was not significiant. Correlation between leaf P and yield was significant for Balaramapuram and also for the pooled data. Leaf K level was positively correlated with yield at Balaramapuram and negatively correlated with yield at Mannuthy. A negative correlation was also found for the laterite soil (i.e., for the population combining the Pilicode and Mannuthy populations). Leaf Ca showed negative correlation with yield in Balaramapuram population (red sandy loam soil) and also in the pooled population. Positive correlations

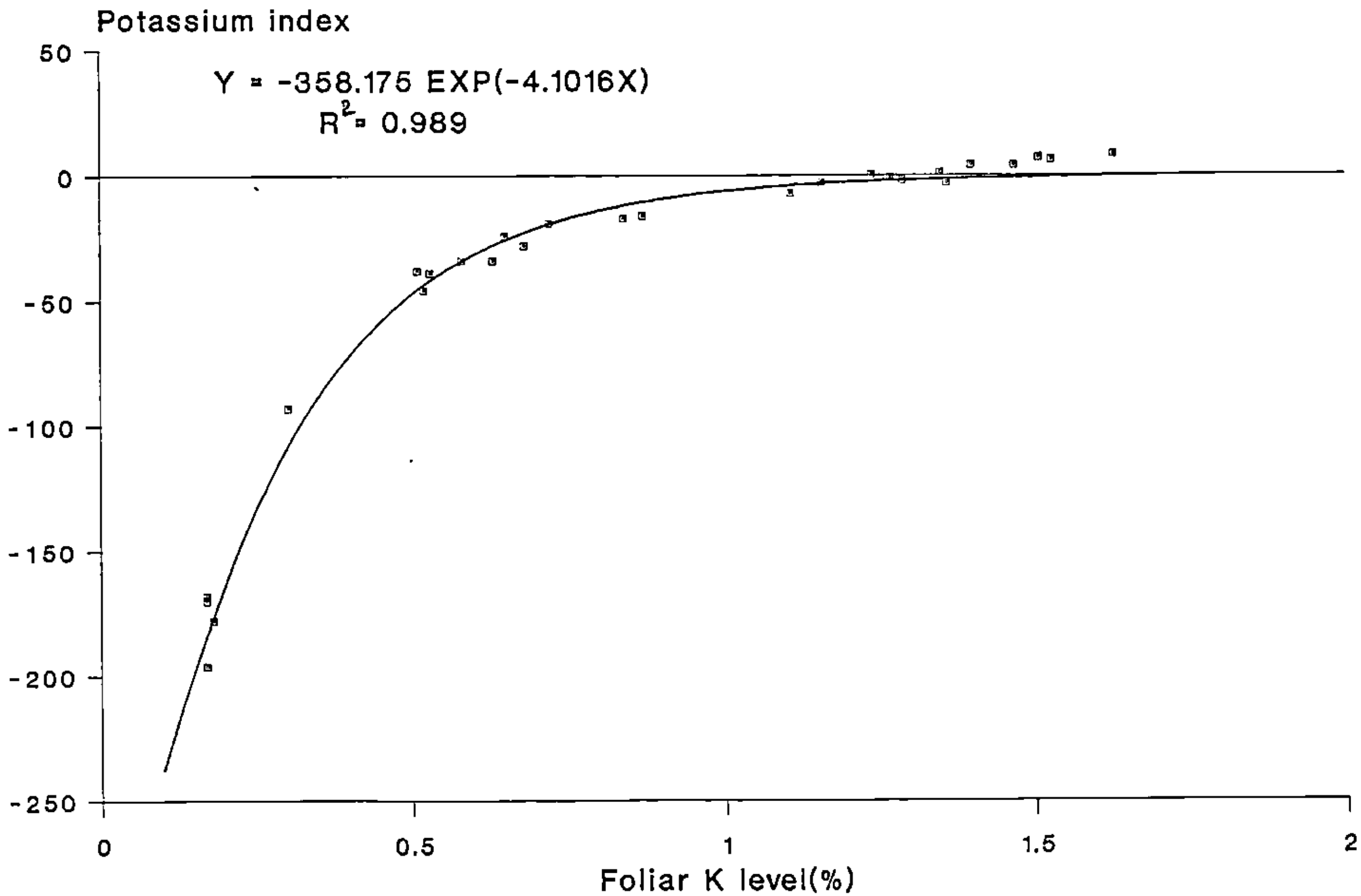

Fig.7 Relationship between potassium index and foliar K level in coconut

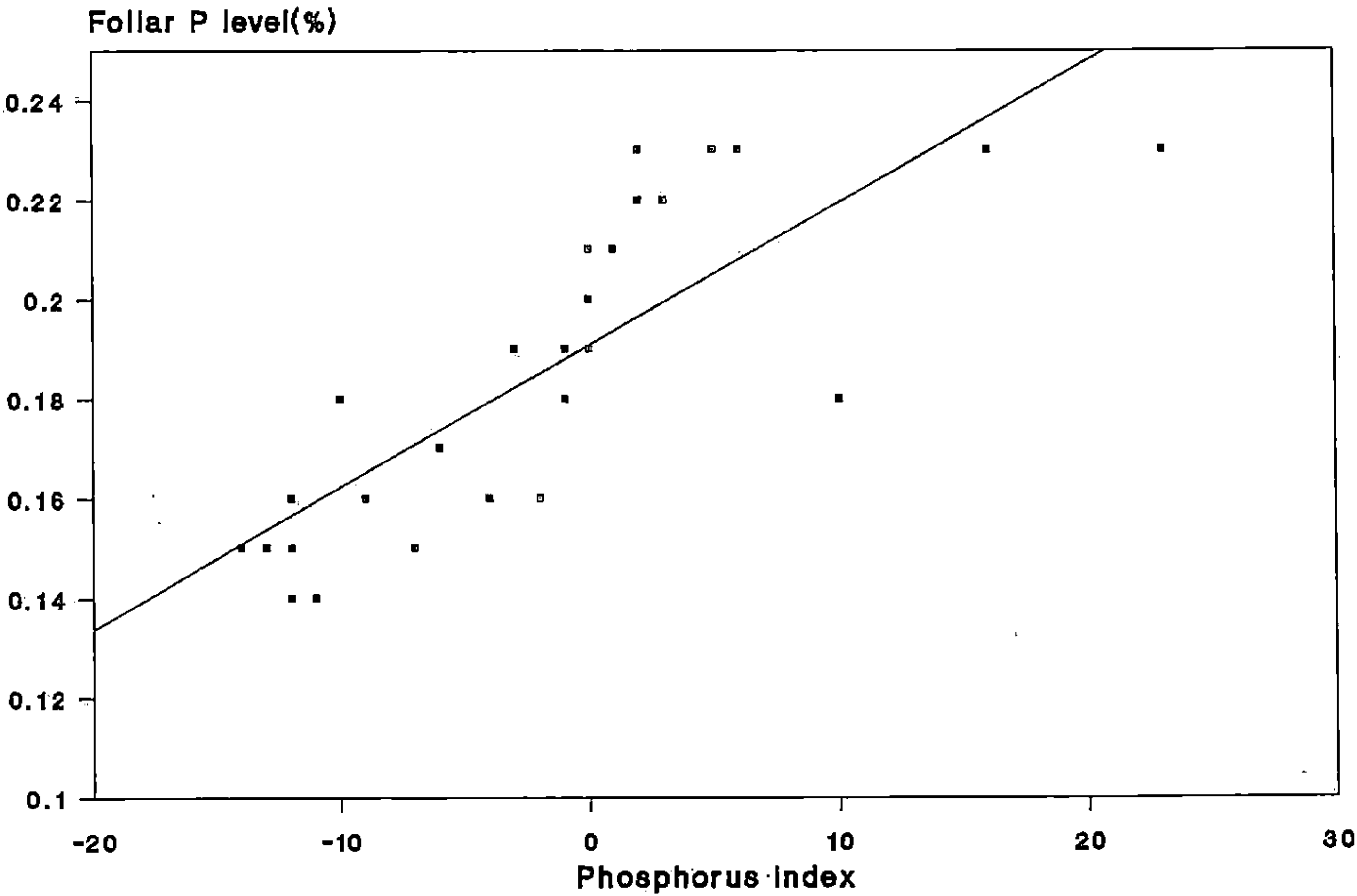

Fig.8 Relationship between phosphorus index and foliar P level in coconut

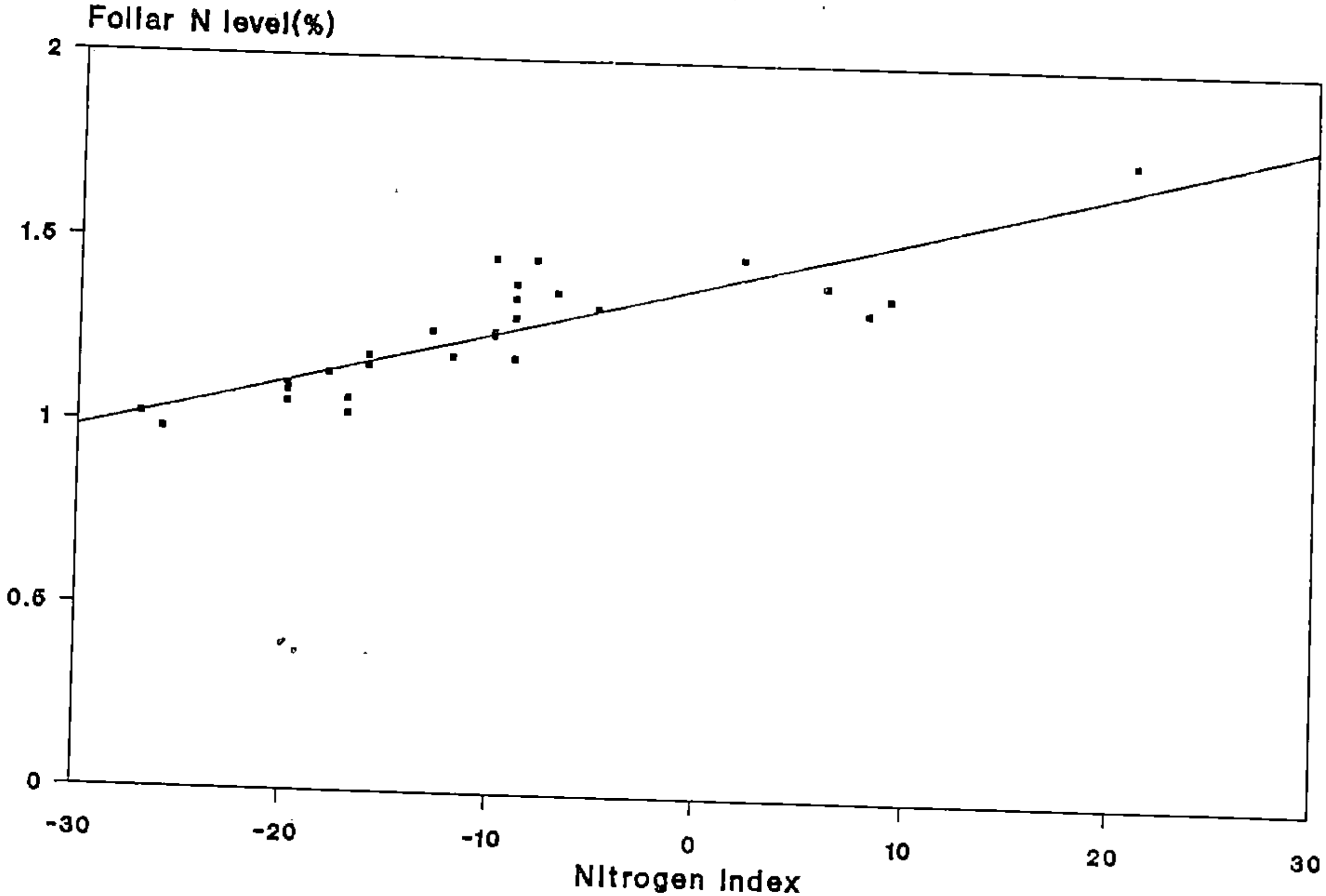

Fig.9 Relationship between nitrogen index and foliar N level in coconut

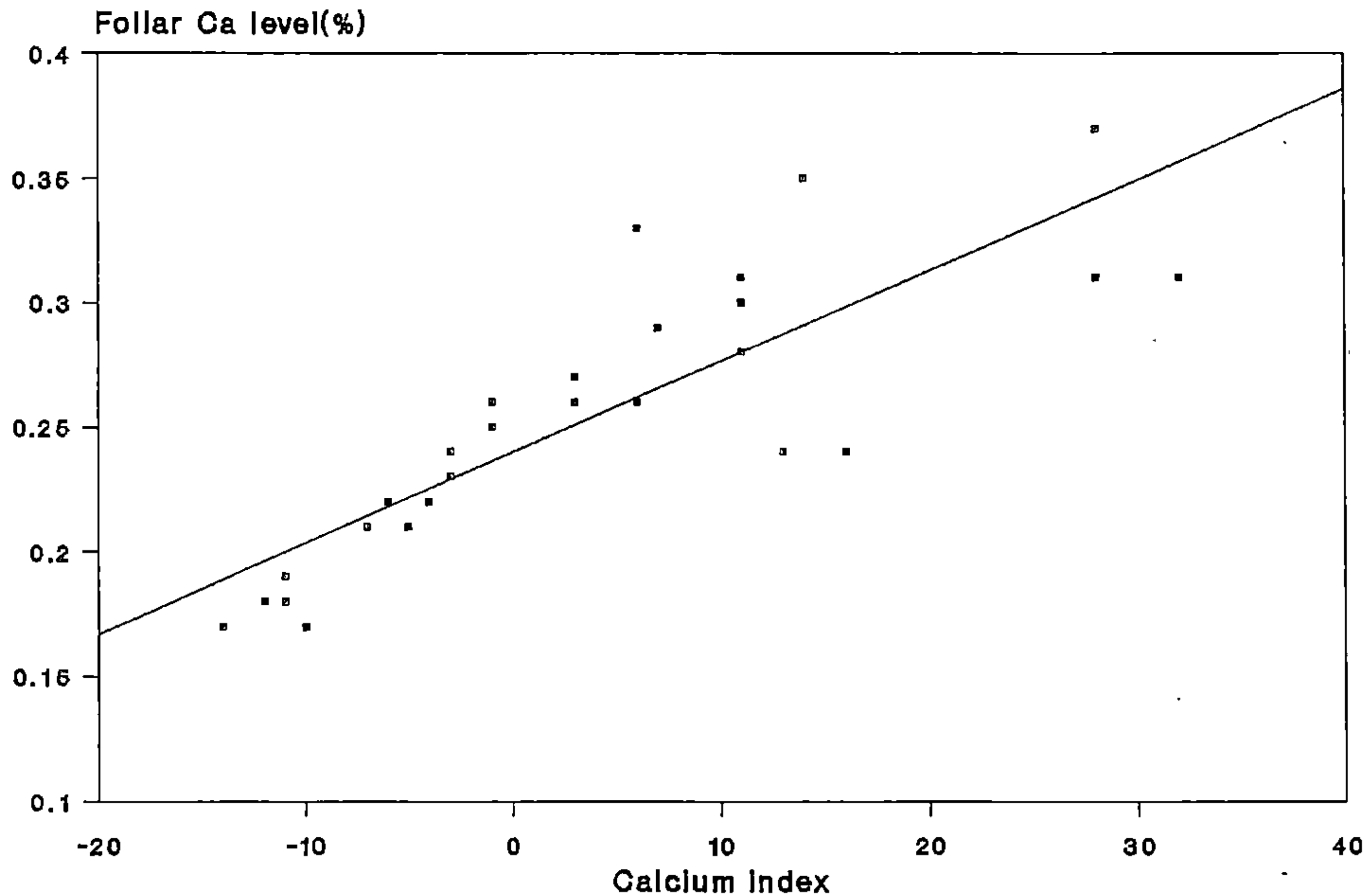

Fig.10 Relationship between calcium index and foliar Ca level in coconut

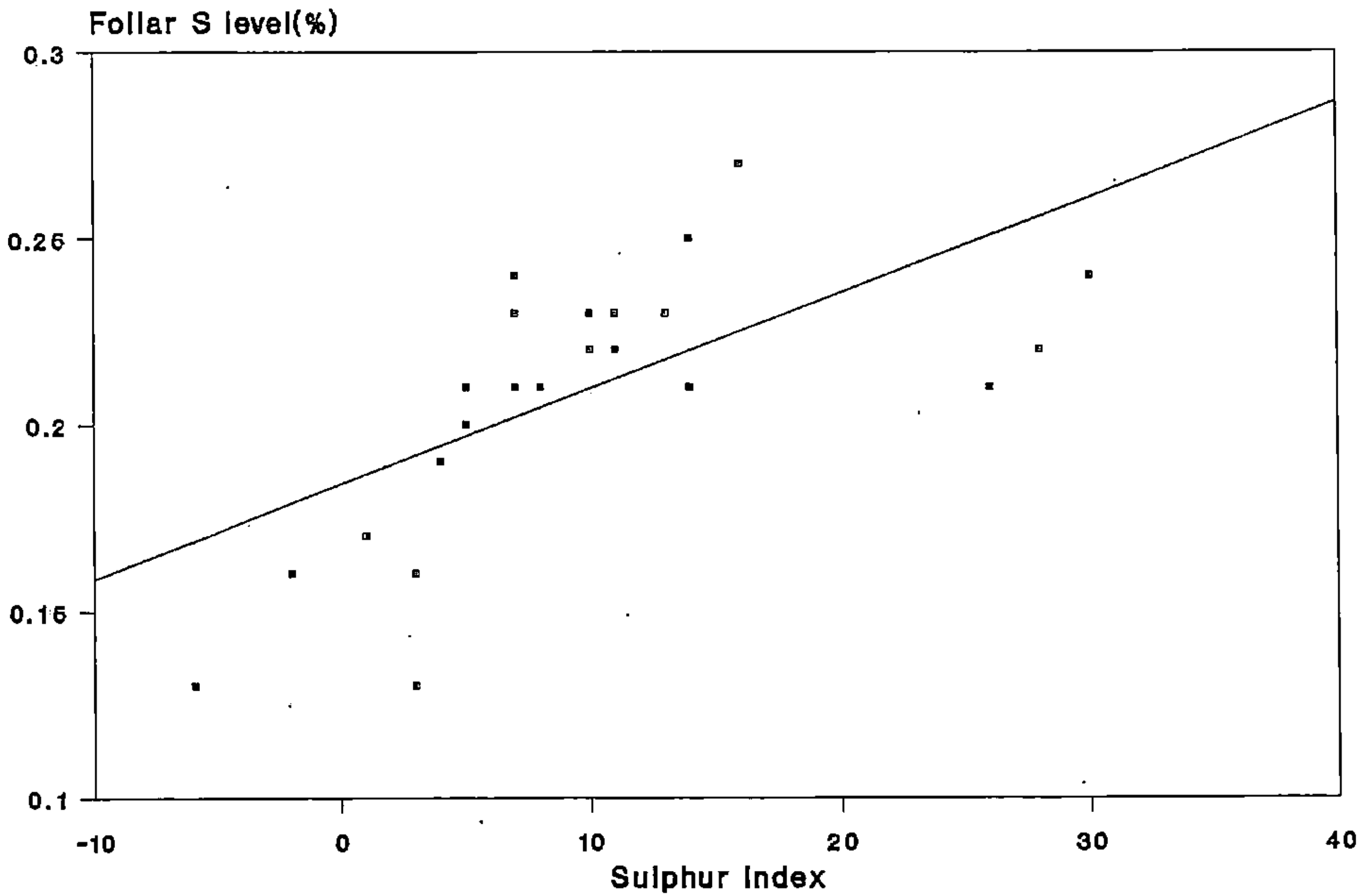

Fig.11 Relationship between sulphur index and foliar S level in coconut

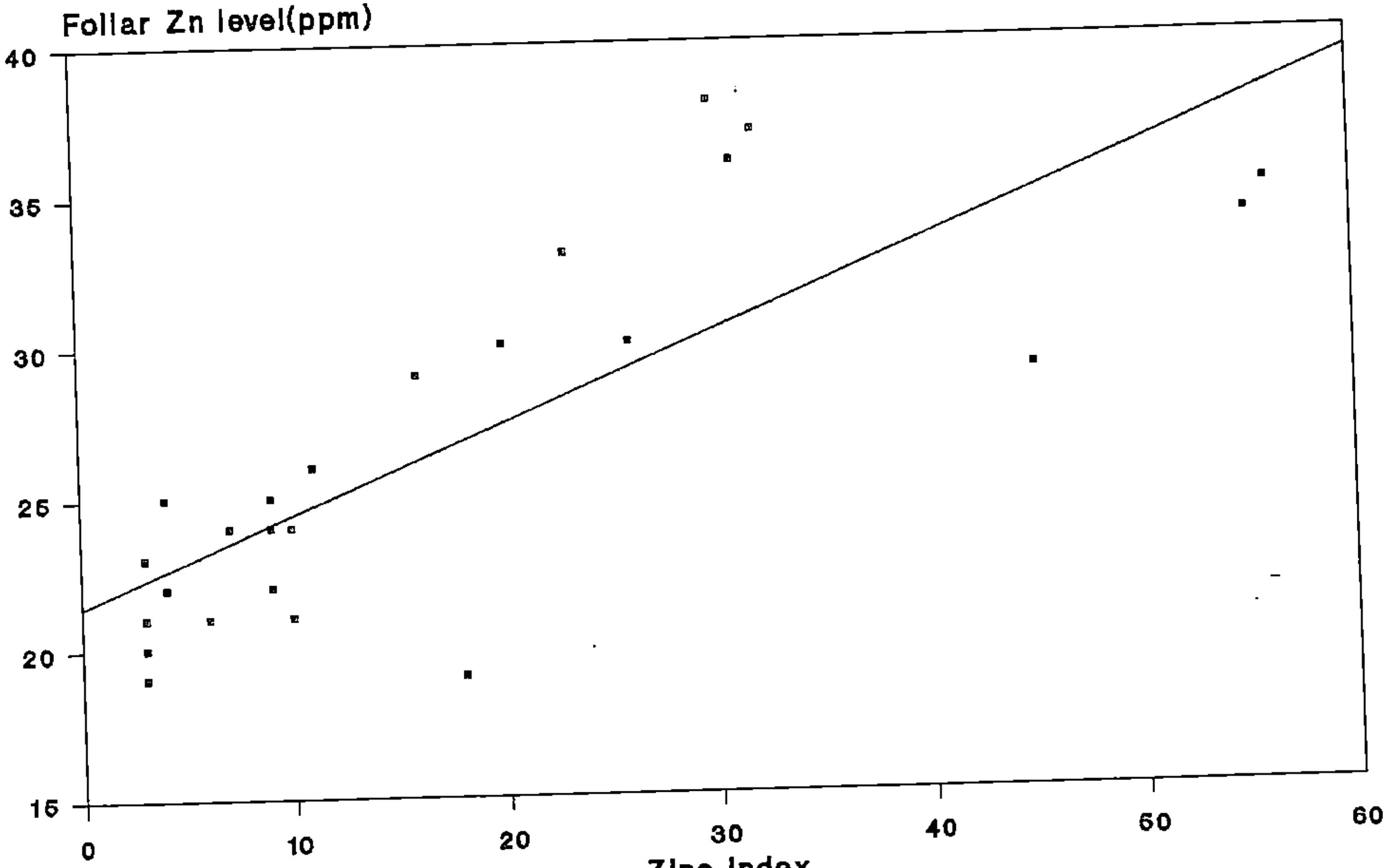

Fig.12. Relationship between zinc index and foliar Zn level in coconut

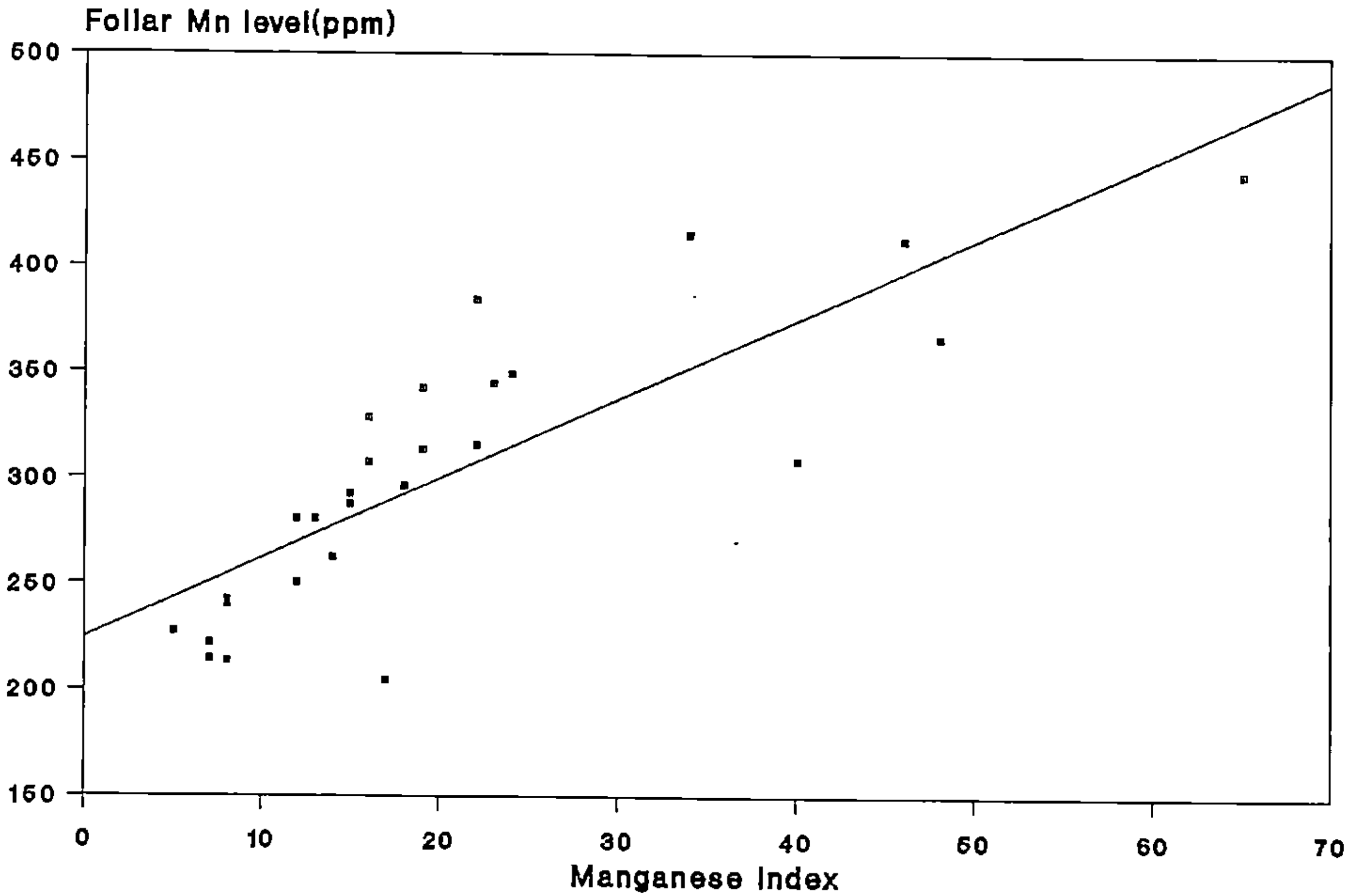

Fig.13 Relationship between manganese index and foliar Mn level in coconut

Table 16. Correlations (r) between foliar nutrient concentrations and yield

Nutrient	Pilicode	Mannuthy	Balaramapuram	Laterite	Pooled
N	-0.855**	0.201	-0.912**	-0.683**	-0.675**
P	-0.247	0.378	0.603**	0.362	0.696**
K	0.154	-0.657**	0.487*	-0.574**	-0.400
Ca	-0.022	-0.195	-0.824**	-0.236	-0.576**
Mg	0.212	-0.202	-0.240	0.001	0.399
S	0.798**	-0.080	0.316	0.573**	0.719**
Cl	-0.125	0.174	0.070	0.068	0.005
Fe	-0.435*	0.486*	0.505**	0.396	-0.213
Zn	-0.428*	0.432*	-0.010	-0.197	0.038
Mn	0.275	0.439*	-0.644**	0.440*	0.217

* Significant at 5% level

** Significant at 1% level

were found to exist between leaf S and yield in the Pilicode population, in the combined population of Mannuthy and Pilicode (laterite soil) and also in the total population combining all the three locations. Foliar Fe level showed negative correlation with yield in Pilicode population while it was positively correlated with yield in Mannuthy and Balaramapuram populations. Yield was negatively correlated with foliar Zn level in the Pilicode population while it was positively correlated in the Mannuthy population. Leaf Mn was positively correlated with yield in Mannuthy population and also in the population combining both Mannuthy and Pilicode. The correlation was, however, negative and highly significant for the Balaramapuram population.

4.11. Relationships between yield and nutrient ratios

Simple correlations (r values) worked out between nutrient ratios and yield for Pilicode, Mannuthy and Balaramapuram populations are given in Table 17. The results indicated that majority of the ratios involving N were negatively correlated with yield in Pilicode and Balaramapuram populations, whereas in the case of Mannuthy, the correlations were not significant excepting for N/K which gave positive correlation and N/Mn which gave a negative correlation.

In the case of ratios involving P, the correlations were generally positive. P/Zn ratio in Pilicode and

Table 17. Correlations (r) between nutrient ratios and yield in coconut populations at the three sampling locations.

Nutrient ratio	Pilicode	Mannuthy	Balaramapuram
N/P	-0.61**	-0.19	-0.72**
N/K	0.72**	0.55**	-0.69**
N/Ca	-0.36	0.17	0.52**
N/Mg	-0.78**	0.31	-0.80**
N/S	0.85**	0.15	-0.77**
N/Cl	-0.77**	0.01	-0.72**
N/Fe	-0.54**	-0.21	-0.70**
N/Zn	-0.04	-0.19	-0.64**
N/Mn	-0.54**	-0.47*	0.23
P/K	-0.27	0.58**	0.42*
P/Ca	0.05	0.38	0.76**
P/Mg	-0.39	0.45*	0.51*
P/S	-0.86**	0.43*	0.42*
P/Cl	-0.23	0.21	0.59**
P/Fe	0.05	0.11	-0.04
P/Zn	0.61**	0.10	0.56**
P/Mn	-0.31	-0.32	0.78**
K/Ca	0.21	-0.28	0.85**
K/Mg	-0.08	-0.38	0.50*
K/S	-0.72**	-0.42*	0.13
K/Cl	0.16	-0.76**	0.52**
K/Fe	0.27	-0.68**	-0.32
K/Zn	0.64**	-0.63**	0.28
K/Mn	-0.03	-0.63**	0.74**
Ca/Mg	-0.03	-0.13	-0.88**
Ca/S	-0.82**	-0.08	-0.78**
Ca/Cl	-0.08	-0.26	-0.78**
Ca/Fe	0.19	-0.25	-0.80**
Ca/Zn	0.53**	-0.33	-0.72**
Ca/Mn	-0.46*	-0.52**	-0.40
Mg/S	-0.72**	-0.04	-0.46*
Mg/Cl	0.25	-0.33	-0.22
Mg/Fe	0.40	-0.32	-0.56**
Mg/Zn	0.68**	-0.44*	-0.20
Mg/Mn	-0.12	-0.60**	0.74**
S/Cl	0.79**	-0.22	.0.18
S/Fe	0.89**	-0.37	-0.40
S/Zn	0.88**	-0.35	0.18
S/Mn	0.59**	-0.49*	0.79**
Cl/Fe	0.17	-0.20	-0.54**
Cl/Zn	0.68**	-0.23	-0.04
Cl/Mn	-0.25	-0.44*	0.71**
Fe/Zn	0.54**	-0.06	0.48*
Fe/Mn	-0.51*	-0.37	0.74**
Zn/Mn	-0.70**	-0.41*	0.66**

* Significant at 5% level

** Significant at 1% level

Balaramapuram populations, P/Mg, P/S and P/K ratio in Mannuthy and Balaramapuram populations, and P/Ca, P/Cl, and P/Mn ratios in Balaramapuram population were positively correlated with yield. The only exception was the negative correlation of P/S ratio with yield for Pilicode population. In all the other cases, the correlations were not significant.

Among the nutrient ratios involving K, K/S in Pilicode and Mannuthy and K/Cl, K/Fe, K/Zn and K/Mn in Mannuthy population were negatively correlated with yield. K/Zn was positively correlated with yield in Pilicode population. Positive correlations with yield were also recorded for K/Ca, K/Mg, K/Cl and K/Mn ratios in Balaramapuram population. Among the significant correlations between yield and nutrient ratios involving Ca, only one ratio namely, Ca/Zn gave positive r value in Pilicode population. In all other cases it was negative. The negatively correlated ratios were Ca/S and Ca/Mn in Pilicode population, Ca/Mn in Mannuthy population and Ca/Mg, Ca/S, Ca/Cl, Ca/Fe and Ca/Zn in Balaramapuram population.

Nutrient ratios involving Mg generally gave significant negative correlations with yield excepting for the positive correlation of Mg/Zn ratio in the Pilicode population and Mg/Mn ratio in the Balaramapuram population. Mg/S in Pilicode and Balaramapuram populations and Mg/Zn and Mg/Mn in Mannuthy population were negatively correlated with yield.

Ratios involving S namely, S/Cl, S/Fe, S/Zn and S/Mn were positively correlated with yield in Pilicode population whereas only S/Mn was positively correlated with yield in Balaramapuram population. In the case of Mannuthy population, only one ratio namely, S/Mn was significantly correlated with yield which was negative.

Among the nutrient ratios involving Cl, Cl/Fe was negatively correlated and Cl/Mn was positively correlated with yield in Balaramapuram population and Cl/Zn was positively correlated with yield in Pilicode population. Cl/Mn was negatively correlated with yield at Mannuthy population. The other ratios were not significant. The nutrient ratios involving Fe were not significant in Mannuthy population. Fe/Zn ratio was positively correlated with yield in Pilicode and Balaramapuram populations. Fe/Mn was negatively correlated with yield in Pilicode and positively correlated in Balaramapuram populations. Zn/Mn was negatively correlated with yield in Pilicode and Mannuthy population and positively correlated in Balaramapuram population.

4.12. Interrelationships among foliar nutrient levels

As in the case of yield, correlation among foliar nutrient concentrations were also worked out for examining their inter- relationships. The results of the correlation analysis in respect of different locations and pooled population are given in Tables 18 to 22.

For Pilicode population, significant correlations were obtained in twelve cases of which the highest r value (-0.898**) was found between N and S followed by the correlation between Ca and Mn, Ca and Mg, Ca and K and Mg and Cl in that order (Table 18). The r values were comparatively much smaller for the other significant correlations. Among the significant correlations obtained, those between N and S and K and Fe were negative.

In the case of Mannuthy population, significant correlations were obtained in six cases (Table 19). The highest r value obtained (0.833**) was for the positive correlation between Ca and Mg followed by those between K and Mn (-0.611**) and that between P and Fe (0.561**). The other significant r values were comparatively smaller.

The Balaramapuram population showed significant correlations among nutrient levels in fifteen cases (Table 20). The highest correlation coefficient was obtained for the relationship between P and Ca (-0.854**). The other

Table 18. Interrelationships among foliar nutrient levels in coconut palms at Pilicode

	N	P	K	Ca	Mg	S	Cl	Fe	Zn
P	0.124								
K	-0.189	-0.248							
Ca	-0.107	0.431*	-0.577**						
Mg	-0.108	0.238	-0.331	0.582**					
S	-0.898**	0.114	0.103	0.280	0.217				
Cl	0.166	0.320	0.085	0.283	0.543**	0.057			
Fe	0.151	0.190	-0.490*	0.354	0.043	-0.069	0.138		
Zn	0.267	0.431*	-0.227	0.419*	0.353	-0.143	0.370	0.438*	
Mn	-0.386	0.075	-0.437*	0.618**	0.013	0.431*	-0.092	0.255	0.069

* Significant at 5% level
** Significant at 1% level

Table 19 Interrelationships among foliar nutrient levels in coconut palm at Mannuthy

	N	P	K	Ca	Mg	S	Cl	Fe	Zn
P	0.363								
K	-0.321	-0.35							
Ca	-0.231	-0.023	-0.077						
Mg	0.160	-0.02	-0.239	0.833**					
S	0.035	0.228	0.007	0.176	0.016				
Cl	0.113	-0.027	0.27	-0.122	-0.116	-0.146			
Fe	0.121	0.561**	-0.316	-0.318	-0.457*	0.326	0.061		
Zn	-0.119	0.249	-0.147	-0.097	-0.287	0.205	0.226	0.317	
Mn	0.404*	0.510*	-0.611**	0.128	0.235	-0.04	-0.128	0.232	0.226

* Significant at 5% level
** Significant at 1% level

Table 20. Interrelationships among foliar nutrient levels in coconut palm at Balaramapuram

	N	P	K	Ca	Mg	S	Cl	Fe	Zn
P	-0.425*								
K	-0.557**	0.085							
Ca	0.722**	-0.854**	-0.331						
Mg	0.282	-0.603**	-0.228	0.619**					
S	-0.274	0.44*	-0.276	0.301	-0.025				
Cl	-0.079	0.195	0.499*	0.009	-0.048	-0.163			
Fe	-0.329	0.385	0.163	-0.312	0.031	0.277	0.292		
Zn	-0.012	0.254	-0.276	-0.025	-0.037	0.458*	0.378	0.209	
Mn	0.62**	-0.46*	-0.559**	0.62**	0.479*	-0.01	-0.116	-0.439*	0.172

* Significant at 5% level

** Significant at 1% level

Table 21. Interrelationships among foliar nutrient levels in coconut palms growing on laterite soil (Pilicode and Mannuthy combined)

	N	P	K	Ca	Mg	S	Cl	Fe	Zn
P	-0.230								
K	0.295	0.405*							
Ca	0.113	0.028	-0.430*						
Mg	0.169	0.41*	-0.369	0.615**					
S	-0.578**	0.692**	-0.211	-0.208	0.120				
Cl	0.212	0.003	0.188	-0.295	0.198	-0.074			
Fe	-0.191	0.652**	-0.230	-0.328	-0.074	0.476*	-0.046		
Zn	0.271	0.071	-0.339	0.287	0.176	-0.177	0.012	0.241	
Mn	-0.545**	0.038	-0.482*	0.383	0.092	0.169	-0.178	-0.057	-0.114

* Significant at 5% level

** Significant at 1% level.

Table 22. Interrelationships among foliar nutrient levels in coconut palm (pooled for all the three locations)

	N	P	K	Ca	Mg	S	Cl	Fe	Zn
P	-0.407*								
K	-0.050	-0.440*							
Ca	0.457*	-0.522**	0.231						
Mg	0.029	0.631**	-0.664**	0.126					
S	-0.473*	0.909**	-0.451*	-0.452*	0.557**				
Cl	0.175	0.059	0.191	-0.399	0.053	0.036			
Fe	-0.099	-0.237	0.486*	-0.022	-0.333	-0.034	-0.141		
Zn	-0.065	0.090	0.181	0.102	0.051	0.176	0.149	-0.169	
Mn	-0.173	0.158	-0.720**	0.295	0.194	0.331	-0.373	-0.448*	0.369

* Significant at 5% level

** Significant at 1% level

highly significant correlations were those between N and Ca (0.722**), N and Mn (0.621**), Ca and Mn (0.62**), Ca and Mg (0.619**), P and Mg (-0.603**) and K and Mn (-0.559**).

When correlations were worked out for the laterite soil (combining Pilicode and Mannuthy populations), significant correlations were obtained in ten cases (Table 21). The highest correlation was seen between P and S (0.692**). The other highly significant correlations were for P and Fe (0.652**), Ca and Mg (0.615**), N and S (-0.578**) and N and Mn (-0.545**). When correlations were worked out for the whole population pooling the three locations, fourteen relationships were found to be significant (Table 22). Among them, highly significant r values were obtained for P and S (0.909**), K and Mn (0.72**), K and Mg (-0.664**), P and Mg (-0.631**), Mg and S (-0.557**) and P and Ca (-0.522**). A summary of these significant correlations among foliar nutrient levels in coconut palm under five different situations are given in Table 23.

Table 23. Summary of significant correlations among foliar nutrient levels in coconut palm

Nutrient	Pilicode	Mannuthy	Balarama-puram	Laterite (Pilicode + Mannuthy)	Pooled
N-S	-ve			-ve	-ve
P-Ca	+ve		-ve		-ve
P_Zn	+ve				
K-Ca	-ve			-ve	
K-Fe	-ve				+ve
K-MN	-ve	-ve	-ve	-ve	-ve
Ca-Mg	+ve	+ve	+ve	+ve	
Ca-Zn	+ve				
Ca-Mn	+ve		+ve		
Mg-Cl	+ve				
S_Mn	+ve				
Fe-Zn	+ve				
N-Mn		+ve	+ve	-ve	
P-Fe		+ve		+ve	
P-Mn		+ve	-ve		
Mg-Fe		-ve			
N-K			-ve		
N-Ca			+ve		+ve
P-Mg			-ve	+ve	
K-Cl			+ve		+ve
Mg-Mn			+ve		
S-Zn			+ve		
P-K				+ve	-ve
P-S			+ve	+ve	+ve
S-Fe				+ve	
N-P			-ve		+ve
Ca-S					-ve
K-Mg					-ve
K-S					-ve
Mg-S					+ve
Fe-Mn			-ve		-ve

Table 24. Correlations between DRIS indices and folliar concentrations of different nutrients in coconut palm

Nutrient	Correlation coefficient	
N	0.861**	
P	0.813**	
K	0.789**	(R^2 = 0.989)
Ca	0.831**	
Mg	0.444*	
S	0.599**	
Cl	0.456*	
Fe	0.325	
Zn	0.788**	
Mn	0.797**	

* Significant at 5% level
** Significant at 1% level
Parentheses denote R^2 value for curvilinear relationship

Discussion

5. DISCUSSION

The data generated from the study were used to develop DRIS norms for coconut palm and also to identify the limitations/inadequacies, if any, of this approach. In addition, an attempt was also made to compare this method with the conventional critical level approach for diagnosing nutritional disorders in coconut.

The locations chosen for the study differed in their soil type and climate. Pilicode represented the northernmost part of Kerala, Mannuthy the central part and Balaramapuram the southern part of Kerala. The selection of the palms for the study was restricted to the populations maintained at the research stations of the university at these locations because of the availability of the yield data of the palms which are required for developing DRIS norms.

The soil type at two locations namely, Pilicode and Mannuthy, was laterite and it was red sandy loam at Balaramapuram. The soils were generally acidic, low in organic matter content, high in available P and available micronutrients. Available K content was less in Balaramapuram soil but it was relatively higher in the laterite soils of the other two locations (Table 3).

5.1. DRIS norms

The diagnosis and recommendation integrated system (DRIS) developed by Beaufils (1957, 1971, 1973) considers nutrient ratios rather than individual nutrient concentrations as being more suitable parameters for diagnosing nutritional disorders in plants. A high concentration of one nutrient may result in the imbalance of another. This implies that in the deranged condition, the ratios involving two nutrients may become either smaller or larger than an optimum value. The impact of the nutrient imbalance on yield is statistically determined based on the variance ratio of the nutrient/nutrient ratio between low-yield and high-yield subpopulations. The forms of expression whose variance ratios are statistically significant provide the criteria for discriminating the low-yielding and high-yielding subpopulations. The mean values of these forms of expression for the high-yielding populations are taken as the DRIS norms or standard values. These norms constitute the most balanced values for the nutrients involved and any departure from this value is an indication of imbalance whose magnitude is given by the distance from the standard values. The DRIS method was reported to be free from the problems associated with the other diagnostic procedures. The method is not affected by age of the plant, location where it is grown, plant part used for the chemical analysis, etc. (Beaufils, 1973; Sumner, 1977 c; Walworth and Sumner, 1987).

The interpretations as generally made from a DRIS chart (Walworth and Sumner, 1987) seem to contradict the very concept of discriminating the low- and high-yield subpopulations based on DRIS norms. For example, Sumner (1982) presented DRIS norms for NPK in corn. The values for N/P, N/K and K/P were 10.04, 1.49 and 6.74 respectively. This should mean that at the intersection of N/P, N/K and K/P axes, the values were 10.04, 1.49 and 6.74 respectively. The inner circle of the DRIS chart which represents the balanced zone had N/P values ranging from 8.7 to 11.6, N/K from 1.3 to 1.7 and K/P from 5.9 to 7.8. A perusal of the mean N/P, N/K and K/P values for the low yielding corn population reported by him were 9.88, 1.39 and 6.94 respectively. If these values are compared with DRIS norms, they will fall within the inner circle. The interpretation would therefore be that the plant with such a composition of N, P and K is nutritionally balanced. Ironically, it cannot be so because these were the mean values for low yielding population. Because of this seemingly contradictory nature, in the present study, the point of intersection of the three axes in the DRIS chart is considered to be the most balanced. The inner circle is considered to represent the zone of slight imbalance; the outer circle, the zone of moderate imbalance and the region beyond the outer circle to represent the zone of marked imbalance. From the DRIS charts presented in Figs. 1 to 5, it may also be observed that in some cases, the zones representing marked imbalance have values that are difficult to obtain in practice. For instance the K/N axis of Fig. 1 shows a lower range of 0.44 which would mean a very high foliar K level or a very low foliar N level compared to generally what is observed.

In the present study, the palms with yields equal to or higher than mean plus SD constituted the high-yielding subpopulation and those with less than or equal to mean minus SD formed the low-yielding subpopulation (Davee et al., 1986). This method was followed to develop DRIS norms for coconut as it provided the low- and high-yielding subpopulations with wider differences than that can be obtained with a single cut-off value to divide the low- and high- yielding groups.

Altogether 33 nutrient ratios could be selected for developing DRIS norms in coconut (Table 5). Using the 33 nutrient ratios, one expects to construct DRIS charts for all possible combinations of ratios involving any three nutrients. However, the very mode of presentation of the DRIS chart limits its flexibility. It allows only such sets of three ratios in which one of the nutrients comes as the numerator or as the denominator twice, to be presented as DRIS charts. For instance, consider three nutrients A, B and C and their ratios namely, A/B, A/C, B/C, B/A, C/B, etc. DRIS charts can be made using the combination of three ratios such as A/B, A/C and B/C in which a nutrient comes as the numerator (or as the denominator) twice but not using the combination like A/B, B/C and C/A. In the present study, only 31 DRIS charts could be constructed from the 33 nutrient ratios presented in Table 5. The DRIS charts shown in Figs. 1 to 5 were drawn using the most significant nutrient ratios (Figs. 2 to 5) and the one involving the most important nutrient elements namely, N, K and Cl. These three nutrients are directly involved in the productivity of the palms and hence are required in large amounts (Wahid, 1984). The nutrient deficiencies met with in coconut gardens in India as well as in the other coconut growing countries are mainly those of N, K, Cl and Mg and to some extent S also (Nelliat, 1973; Bopaiah and Cecil, 1991; Wahid et al., 1974). The DRIS norms and DRIS charts developed in this study cover all these nutrients and therefore can be used for diagnosing the nutrient imbalances in coconut palm.

The method of presentation of DRIS chart may be illustrated as follows. Consider Fig.1 for the purpose. This chart relates to N, K and Cl in terms of their ratios. The balance or imbalance among these three nutrients can be found out from this DRIS chart. The point of intersection of the three axes representing N/Cl, K/N, and K/Cl corresponds to their respective DRIS norms i.e., their mean values for the high-yielding subpopulation. Thus the values represented by K/N, K/Cl and N/Cl axes at the point of intersection are 0.86, 1.98 and 2.43 respectively. These values constitute the most balanced condition for these three nutrients. The departure from this point to either side of the point of intersection indicates increasing imbalance. This can happen due to the excess of one nutrient or the insufficiency of the other. The magnitude of imbalances may be displayed using two concentric circles. The diameter of the inner circle is set at 4SD/3 where SD is the standard deviation for the high-yielding subpopulation and that of the outer circle is set at 8SD/3 as shown in Fig. 1 (Beaufils, 1971; Walworth and Sumner, 1987). The values falling within the inner circle are considered to be more balanced than those falling within the outer circle. Marked imbalance occurs beyond the outer circle. The degree of imbalance between the two nutrients of a ratio thus increases from the centre of the circle towards the outer. This is denoted by a horizontal arrow (->) in the inner circle, by an arrow at 45^{o} to the horizontal (↗) or (↖) in the outer circle and by vertical arrows (↑) or (↓) beyond the outer circle. Because the excess of one nutrient corresponds to a shortage of another in terms of balance, only insufficiencies are recorded by convention, for the purpose of diagnosis. Identical diagnoses are obtained by considering either excesses or insufficiencies or both.

The way in which the DRIS chart can be used for diagnostic purpose may be illustrated with an example. Consider that K, N and Cl concentrations in a test sample on drymatter basis are 1.8%, 2.0%, and 0.48% respectively, which give the values of K/Cl as 3.75, N/Cl as 4.17 and K/N as 0.90. In the present example, the value of the function K/Cl lies beyond the outer circle (Fig.1) in the zone of Cl insufficiency giving a) K Cl ↓ N. The value of N/Cl also lies outside the outer circle in the zone of Cl insufficiency giving b) N ↓ Cl ↓ K and the value of K/N lies within the inner circle in the zone of balance giving c) N ↓ Cl ↓ K. The final reading then becomes K → N ↓ Cl which gives the orderof requirement for K, N and Cl in terms of limiting importance on yield as Cl > K = N. This does not necessarily mean that K and N are sufficient, instead; it should be considered a relative ranking of the nutrients according to their requirements. In this way, DRIS chart involving any other set of three ratios can also be developed and utilised for diagnostic purpose.

5.2. DRIS index

It may be noted that the use of DRIS chart is restricted to a qualitative assessment of nutritional imbalances involving three nutrients. The DRIS technique also provides another approach that can accommodate any number of nutrient ratios. In this approach nutrient indices were worked out using standard values or norms and the observed nutrient ratios for the plant under test.

The DRIS index for a nutrient indicates its relative abundance among the nutrients considered in its computation. Lower the value of the index for a nutrient, greater is its requirement (Walworth and Sumner, 1987). The DRIS index of a nutrient is also related to its foliar nutrient concentration (Table 24, Figs. 7 to 13). Among the 10 nutrients tested, the relationship between DRIS index and foliar level failed to attain statistical significance only in the case of Fe. In all the other cases, the correlations were significant. The high correlations existing between the DRIS indices of N, P, K, Ca, S, Zn and Mn and their foliar levels indicate that the DRIS indices of these nutrients are mainly determined by their own levels in the foliage. In the case of K, however, the exponential model fitted better than the linear model (Fig. 7). The relationship indicated that below a foliar level of 0.6 per cent, large differences occur in K index with relatively small changes in the foliar concentration. The reverse is true for foliar levels higher than 0.6 per cent.

Reasonably good agreement can be observed between the NPK treatments and N, P and K indices (Table 7). Thus the DRIS indices for N, P and K were more negative for their zero levels. The index of a nutrient became more positive with increasing level of the applied dose when comparison was made keeping the levels of the other two nutrients constant. The shift in DRIS index of a nutrient towards more positive side implies that its requirement was lessened. Comparison of the indices for a particular nutrient at the three levels of applications reflects the extent to which the nutrient is limiting the yield in each of these cases.

Although there were improvements in N, P and K indices with increasing level of application of these nutrients, corresponding increase in yield was not observed in all the cases (Table 7). Only K had shown an increase in yield corresponding to the decrease in DRIS index following the application of the nutrient.

5.3. Nutrient imbalance index

The overall nutritional status of the plant is given by the nutrient imbalance index (NII) (Walworth and Sumner, 1987). The NII values were found to be negatively correlated with nut yield ($r^2 = 0.543$). The relationship was however better explained by a quadratic model yielding an R^2 value of 0.673 (Fig. 6). Negative relationship between NII and yield ($r = -0.736^{**}$) is a direct indication of the reduction in coconut yield with increasing nutrient imbalance (Fig. 6). Although NII may be considered as an index of the overall imbalance of nutrients in the palm, it does not tell which nutrient is limiting. That is to say, it is likely to obtain more or less the same NII values for more than one case even if the limiting nutrient is different for each. For instance, the NII values obtained for palms receiving N1P1K2 and N2P0K2 treatments were the same (Table 7). However, in the former case, the nutrient which was lacking was N and in the latter case it was P. So much so, the NII does not provide a diagnostic tool in identifying the limiting nutrient, though it gives an indication of the degree of nutrient imbalance in the plant system.

5.4. Factors influencing DRIS

a. Criterion employed in categorising low- and high-yield groups

According to Walworth and Summner (1987), the cut-off value used to divide the low- and high-yield groups is not critical so long as the high yield data remain normally distributed. Letzsch and Sumner (1984) had also shown that DRIS norms varied only marginally when cut-off value for dividing high and low corn yield was changed substantially. This would mean that DRIS norms developed for a crop are rather independent of the cut-off value used to divide the low- and high-yield subpopulations. Whether this could be true for coconut also was investigated by comparing the DRIS norms developed already (according to the method of Davee et al., 1986) with the DRIS norms developed using two different yield cut-off values namely, 80 and 60 nuts per palm per year.

A comparision of the data given in Tables 5, 8 and 9 indicated that there were differences not only in the forms of expression but also in their number that could be selected. In the case of individual nutrient elements, N and Mg could be selected based on all the three criteria. Similarly 16 nutrient ratios namely, N/P, N/Mg, N/S, N/Cl, P/K, P/Ca, P/Fe, Ca/Cl, Ca/Zn, Ca/Mn, Mg/S, Cl/Mg, Cl/S, Fe/S, Zn/Mg and Zn/S could also be selected by the three different methods. The discrepancies in the DRIS norms were also found even for the nutrients or the nutrient ratios selected by the three methods. Obviously, the DRIS norms are affected by the criterion used to divide the population of the coconut palms into low- and high-yielding groups.

b. Soil type

Considerable differences were observed in DRIS norms developed for coconut palms growing on different soil types namely, laterite and red sandy loam (Tables 10 and 11). A comparison of these data with the DRIS norms developed for the total population (Table 5) also indicated discrepancies in the forms of expression as well as in their number that could be selected in each of these categories.

c. Location

When a comparison was made of the DRIS norms developed for laterite soil in two different locations and for the total population, variations were also found in not only the forms of expression but also in the number of expressions that could be selected (Tables 5, 12 and 13). These differences can only be ascribed to the climatic conditions prevailing in these regions (Appendices 1 and 2). Similar locational differences in DRIS norms were reported for soyabean by Beverly et al. (1986).

d. Interrelationships among foliar nutrient levels

The foliar level of a nutrient is influenced by the levels of certain other nutrient(s). The inter-relationships among foliar nutrient levels were influenced by soil type and location (Tables 18 to 22). A notable feature of these relationships is their inconsistency in the different situations considered. For example at Pilicode, the relationship between N and S was negative and highly significant. However, at Mannuthy where also the soil type was laterite, the relationship between N and S was not significant. This was also true for the palms at Balaramapuram where the soil type was red sandy loam. The pooled analysis for the laterite locations and for all the three locations indicated, however, a significant negative correlation between N and S, quite possibly due to the inclusion of Pilicode data. A summary of the correlation analysis done for the different situations is given in Table 23. The only relationship between any two nutrients that had given consistent result in the five situations studied was the negative relationship between K and Mn. The other correlation which gave consistent results in four out of the five situations was that between Ca and Mg.

The data generated from the present study provide sufficient evidence of the influence of soil type as well as weather (compare between Pilicode and Mannuthy) on the relationships among the foliar levels of different nutrients. That the fertilizer management could also influence the foliar nutrient levels of the unapplied nutrients in coconut palm was reported by Kamala Devi et al. (1975). Their results indicated that as a result of regular application of ammonium sulphate, the soil pH was drastically reduced enhancing dissolution of soil Mn and its greater absorption by coconut palm.

In view of the differences between soil types, locations etc., the nature and magnitude of the correlations may be considered to reflect mainly the indirect effect rather than the direct impact of one nutrient on the other during their absorption by the palm. There are, however, instances of direct effects of one nutrient on the absorption of the other. For instance, the antagonistic effect of K on Ca and Mg is well established (Wahid et al, 1974). In the present study also, a few cases of such antagonistic interaction between K and nutrients like Ca and Fe were observed (Tables 18 to 22).

It is therefore apparent that DRIS index may not necessarily reflect the need for application of the nutrient with lower index but that its index or its order of requirement could be changed by the application of another nutrient. Suppose one considers the first three nutrients showing the lowest indices for fertilizer application (Table 7), it is likely that not all the three nutrients are to be supplemented through fertilizer for improving their indices. It can also happen that with the application of one nutrient, the balance could be very much altered and the indices of the other two nutrients improved. This is self-evident from the data given in Table 7. It may be observed that although the nutrients applied to the palms were N, P and K (and also S, Cl and Ca being the other ingredients in the fertilizer materials used), their application has not only influenced their own DRIS indices but also those of the others as well. For example from Table 7 it may be seen that the P index for N1P0K0 was -12 and that for N2P0K0 was -2. Thus, as a result of N application the P index as well as the order of requirement of P changed. Indirectly, these results imply the order of requirement of a nutrient based on DRIS index is a poor indicator of the necessity for the application of that nutrient.

e. Relationship between yield and nutrient status

A comparison of the nature of relationship between nutrient ratios and yield on one hand and nutrient levels and yield on the other would indicate that the relationships between nutrient ratios involving a particular nutrient and yield were very much influenced by the nature and magnitude of the relationship between that nutrient and yield. This interdependence could be a major factor for the statistical significance of the variance ratios of several nutrient ratios involving a particular nutrient rather than the importance of the ratios themselves (Table 17). For instance, the variance ratio for N is significant and foliar N level is significantly correlated with yield (Table 16). The ratios N/P, N/Mg, N/S, N/Cl etc. had also given significant variance ratios (Table 5) probably because the foliar N level was significantly correlated with yield. This would mean that the importance of the denominator nutrients in their ratios is much less than the dominant numerator nutrient.

The results of the present study also indicated that not all the nutrient ratios are important from the point of view of productivity of the palm. In all the situations tried, less than 50% of the total number of nutrient ratios (90) were found to be giving significant variance ratios between the low and high yielding groups. It was also observed that the nutrient ratios which were correlated with yield were not only few but varied with locations (Table 17). Apart from the ratios involving the major nutrient elements namely, N, P and K, not much work has been done on the practical applicability of DRIS approach in correcting deficiency and/or imbalances in the other nutrients.

Similarly correlation analysis also indicated that the foliar levels of all the nutrients were not related to the productivity of the palm (Table 16). Among the nutrients studied, consistent relationships in majority of the cases were observed for N, K, S, Fe and Mn. Among these, N gave consistently higher and negative r values in laterite (Pilicode) and red sandy loam soils (Balaramapuram). The only exception was the laterite soil at Mannuthy. The negative correlation between foliar N level and yield is misleading. It should not be assumed that the foliar N levels encountered in the coconut populations under study are far in excess of its requirement (Table 4). Still higher levels of foliar N were found to be associated with higher yields (Nelliat, 1973). On the other hand, the negative relationship between foliar N and yield must be considered to reflect the deleterious effects of regular application of N fertilizers on soil health (Anilkumar and Wahid, 1989).

5.5. DRIS versus critical nutrient level approach

Chemical diagnosis based on foliar analysis employing critical nutrient level concept has become the most widely accepted method for diagnosing the nutrient deficiencies in coconut. The critical level of a nutrient is defined as that level below which the plant is likely to respond to the application of that nutrient. Generally, critical levels of nutrients are determined with respect to yield. According to Wahid (1984), the essential nutrient elements in coconut can be grouped into two, one group comprising N, K and Cl, for which the critical nutrient level concept can be successfully applied and the other group consisting of P, Ca, Mg, S and probably all the micronutrients as well for which the concept is difficult to apply; the reason being that the gap between the level of sufficiency and the level of deficiency is too narrow to be clearly defined.

The 14th frond is generally used for the foliar diagnosis in coconut (Fremond et al., 1966). Although, several workers have proposed critical levels for different nutrients in coconut, the critical levels suggested by Manicot et al. (1979a, 1979b, 1980a, 1980b)are used here for comparing with the DRIS norms to evaluate their efficiency in diagnosing the nutrient deficiencies and/or imbalances. The critical levels of major nutrient elements suggested by these workers were

1.8 to 2.0% for N, 0.1 to 0.12% for P, 0.8 to 1.0% for K, 0.3 to 0.4% for Ca, 0.24% for Mg, 0.5% for Cl and 0.15 to 0.2% for S. Since critical levels for micronutrients have not been established with certainty they were not considered.

The critical level approach indicated deficiency of N in all the palms irrespective of the level of applied N (Table 15). Although foliar N level increased following the application of N, it was still below the critical level. The improvement in foliar N level with N application thus suggested reduced severity of N deficiency. In none of the treatments compared, the foliar levels of P indicated deficiency based on its critical level. In the case of K, foliar level increased or decreased depending on the level of applied K. By and large, the interpretations based on DRIS and critical level approach in respect of N and K nutrition of the palms are agreeing with each other. The critical value approach had also shown deficiencies of Ca and Mg in many cases. In contrast, DRIS indices had shown the imbalances of Fe and Cl and also Ca in a few cases.

The deficiencies/imbalances of nutrients identified by both methods did not, however, reflect in yield improvement in all the cases when the deficient nutrient was applied to the palm. Only in the case of K, could the correction of the deficiency and consequent increase in yield be achieved as was evident from the comparison of K0 and K2 treatments (Tables 7). Two different trends were observed in the case of N and P. Although N index was improved by N application, a corresponding increase in yield was not observed (Table 7). On the other hand, irrespective of the level of applied N, foliar N level remained below the critical level in all the cases (Table 14) suggesting that a still higher level of N is required. Both these trends are rather misleading. These anomalies may, however, be explained taking into account the impact of N fertilization on soil health. According to Anilkumar and Wahid (1989), the lack of yield response to N application in these palms was due to the soil acidification and erosion of soil K as a result of regular application of ammonium sulphate, the N source used in the experiment. Going by these observations, it may be stated that DRIS method has failed to provide useful recommendations in respect of N fertilization. Perhaps, soil test coupled with foliar analysis would have been more useful in this context.

In the case of P, correction of imbalance diagnosed through DRIS did not improve the yield as could be inferred from the yield of palms receiving the same levels of N and K but different levels of P. The diagnosis based on critical level approach indicated absence of P deficiency in any of this palms. To that extent, the critical level approach appears to be more accurate than the DRIS method in diagnosing P deficiency.

It may be concluded that DRIS method does not offer an alternative approach to critical nutrient level concept. However, DRIS indices may be considered to supplement information on the balance or imbalance of nutrients in the plant system when diagnosis of nutrient deficiencies in coconut palm is done employing critical level approach.

Summary

6. S U M M A R Y

An investigation on the applicability of diagnosis and recommendation integrated system (DRIS) in coconut palm (*Cocos nucifera* L.) was carried out during 1991-'94. The study was conducted with standing crop of coconut var. West Coast Tall at three research stations of the Kerala Agricultural University namely, Regional Agricultural Research Station, Pilicode; Agricultural Research Station, Mannuthy and Coconut Research Station, Balaramapuram. The objectives of the experiment were to develop DRIS reference norms for major, secondary and micronutrients for diagnosis of nutrient balance in coconut palm and to evaluate the accuracy of the diagnosis by this method.

The palms selected for the study were middle aged (30 to 40 years) having wide variation in their yield. The yield data used for the selection of palms were the means of yields recorded by the individual palms during the past six years(1986-1991). The soil type at Pilicode and Mannuthy was laterite (Ultisol) while it was red sandy loam (Alfisol) at Balaramapuram. The soils were generally acidic, low in organic matter content, high in available P and available micronutrients.

Three hundred and thirty palms from Pilicode with an yield range of 5.8 to 153 nuts, 170 palms from Mannuthy (yield range 8.4 to 137.7 nuts) and 300 palms from Balaramapuram with an yield range of 28.3 to 162.7 nuts per palm per year were selected for developing DRIS norms. All these palms were grown under rainfed condition with uniform management practices according to the package of practices recommendations of the Kerala Agricultural University. In order to test the accuracy of foliar diagnosis made through DRIS, palms under an on-going 3^3 NPK fertilizer experiment at the Coconut Research Station, Balaramapuram was used.

Leaf samples were collected from the 14th frond and were analysed for their chemical characteristics namely N, P, K, Ca, Mg, S, Cl, Fe, Zn and Mn employing titrimetric, spectrophotometric, flame photometric and atomic absorption spectrophotometric methods. The important findings from these studies are summarised as follows:

The foliar N content of Balaramapuram samples recorded the highest N content of 1.65% followed by Pilicode (1.52%) and Mannuthy (1.45%). Mean P content was also higher in Balaramapuram samples and the lowest in the Pilicode samples. In the case of K, palms at Mannuthy recorded the highest mean value of 1.34% followed by Pilicode (1.29%) and Balaramapuram (1.24%). The lowest content of Mg (0.17%) and S (0.1%) were recorded by Pilicode population and the highest by Balaramapuram population.

DRIS norms were developed using the data generated by the chemical analysis of leaf samples using the criterion of Beaufils (1973). To distinguish between the low- and high-yielding subpopulations mean + standard deviation and mean - standard deviation were used (Davee, *et. al*. 1986).

The means and variances of individual nutrients as well as their ratios (totalling 90 including inverse ratios) were worked out for the two subpopulations. The variance ratios were then computed for each nutrient and each nutrient ratio to examine their statistical significance and those discriminating significantly between the two groups were considered for DRIS norms. When both nutrient ratios and its inverse forms were significant, the one which had a higher variance ratio was selected. Mean values of the selected individual nutrients and nutrient ratios of the high yielding subpopulations formed the DRIS norms.

Five nutrients namely, N, P, Ca, Mg and Cl and 33 nutrient ratios were selected on the basis of higher variance ratios as DRIS norms. The norm values for N, P, Ca, Mg and Cl are 1.52, 0.19, 0.245, 0.199 and 0.638 respectively.

Among the N-based ratios six ratios, namely, N/P, N/Mg, N/S, N/Cl, N/Fe and N/Mn were selected. The norm values for N/P is 8.36, N/Mg - 7.68, N/S - 9.46, N/Cl - 2.43, N/Fe - 57.94 and N/Mn- 80.12 respectively.

For the P-based ratios the norm values are P/K- 0.167, P/Ca- 0.537, P/S- 1.16 and P/Fe- 7.41 while for K based ratios it is 0.863, 1.98, 49.56, 645.9 and 68.7 for K/N, K/Cl, K/Fe, K/Zn and K/Mn respectively.

In the case of Ca ratios the norm values are Ca/N- 0.168, Ca/S- 1.58, Ca/Cl- 0.39, Ca/Fe- 9.2, Ca/Zn- 124.9 and Ca/Mn- 12.29 respectively. For Mg ratios the norm values are 0.172, 0.862, 1.25 and 10.53 for Mg/K, Mg/Ca, Mg/S and Mg/Mn respectively.

Among S based ratios only S/K was selected with a norm value of 0.154. Cl/Mg and Cl/S has the norm values of 3.26 and 4.1 respectively. Fe/S has the norm value of 0.19 and Zn/Mg, Zn/S and Zn/Mn has DRIS norm values of 0.011, 0.013 and 0.108 respectively while Mn/S has the norm value of 0.137.

Thirtyone DRIS charts involving selected three nutrient combinations can be constructed from the 33 selected nutrient ratios. A qualitative assessment of nutritional imbalance involving three nutrients and its relative ranking is possible by utilising the DRIS charts. DRIS charts were presented in the thesis for the five most significant three nutrient combinations namely, N-K-Cl, N-Mg-S, Ca-S-Cl, Cl-Mg-S and Zn-Mg-S.

DRIS technique also provides another approach that can accommodate any number of nutrient ratios. In this approach nutrient indices are worked out using DRIS norms and the observed nutrient ratios for the plant under test. The DRIS index for the nutrient indicate its relative abundance among the nutrients considered in its computation. Lower the value of the index for a nutrient, greater is its requirement.

The DRIS index of a nutrient is related to its foliar nutrient concentration. Among the ten nutrients tested the relationship between the DRIS index and foliar level failed to attain statistical significance only in the case of Fe.

The accuracy of diagnosis of nutritional imbalance by DRIS approach was tested for ten selected nutrients in palms receiving varying levels of NPK under a factorial experiment. For this purpose DRIS indices were computed and it was observed that DRIS index for a nutrient varied not only with the applied level of that nutrient but also with the applied level of other nutrients. An improvement in yield with increase in DRIS index value was obtained for the application of K. Similar yield response was not obtained for N and P.

The overall nutritional balance of a palm is given by the nutrient imbalance index (NII). The nutrient imbalance index is the sum of the nutrient indices disregarding the sign (absolute value). A negative significant correlation at 1% level was obtained between NII and yield indicating a reduction in yield with increasing nutritional imbalance. The R^2 value for a curve-linear equation was 0.673 indicating the strong relationship between NII and yield.

A comparison of DRIS norms with different yield cut-off values namely, 80 and 60 nuts per palm per year with the method of Davee et al. (1986) has shown that DRIS norms are affected by the criterion used to divide the population of coconut palms into low- and high-yielding groups.

DRIS norms developed for palms growing on laterite and red sandy loam soils have shown considerable differences in the number of nutrient/nutrient ratios selected as well as the norm values. Similar variations in DRIS norms could also be observed between palms grown on the same soil (laterite), but under two different locations, namely, Pilicode and Mannuthy, indicating climatic influence on DRIS.

The correlations between foliar nutrient levels and yield has shown that all the nutrients were not directly related to the productivity of the palm. Consistent relationship between foliar nutrient level and yield were observed for N, K, S, Fe and Mn. Among these foliar N was negatively correlated with yield at Pilicode and

Balaramapuram. Leaf K level was positively correlated with yield at Balaramapuram and negatively correlated with yield at Mannuthy. Positive correlations were also obtained between leaf S and yield in the Pilicode, laterite soil and pooled population.

Simple correlations between nutrient ratios and yield at different locations showed that many of the nutrient ratios are correlated with yield. A comparison of the relationship between nutrient ratios and yield on one hand and nutrient levels and yield on the other indicated that the relationship between nutrient ratios involving a particular nutrient and yield were very much influenced by the nature and magnitude of relationship between that nutrient and yield.

The intercorrelation among different nutrients showed that foliar level of a nutrient is also influenced by the levels of certain other nutrients. This inter-relationships among foliar nutrient levels were influenced by soil type and location. Among the five situations studied namely, Pilicode, Mannuthy, Balaramapuram, laterite soil group and pooled, K and Mn had shown consistent negative relationship in all the situations while Ca and Mg had shown positive correlation in four out of the five cases.

A comparison of the nutrient deficiency diagnosis by DRIS and critical level approach on a 3^3 factorial experiment has shown that the DRIS and critical level approach in respect of N and K nutrition of the palms are agreeing with each other. However, in the case of P, the critical level approach has not shown deficiency in any of the 27 treatments compared while DRIS approach has shown deficiency in control palms.

It could be concluded that the DRIS approach does not offer an alternative approach to critical level concept but suppliments information on the balance or imbalance of nutrients in coconut palm. Thus diagnosis and recommendation integrated system is applicable to coconut palms and it could be used for nutrient management programmes beneficially in conjunction with critical level approach.

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* Original not seen.

Appendices

Anexure 1

Weather data (monthly average) of Regional Agricultural Research Station Pilicode

Month	Temperature(o C) max.	min.	Relative humidity (%)	Rain fall Rainy days	Rainfall (mm)
January	33.90	21.80	76.00	0	0.00
February	35.80	22.60	76.00	0	0.00
March	38.20	23.90	77.00	0	0.00
April	39.30	25.70	75.00	2	20.20
May	36.60	25.90	79.00	10	309.30
June	30.90	23.50	91.00	27	1066.90
July	28.60	23.70	93.00	27	958.30
August	29.00	23.40	93.00	24	652.50
September	31.60	23.40	91.00	7	274.80
October	32.20	22.80	87.00	10	180.40
November	31.90	22.20	80.00	2	36.30
December	33.70	20.20	75.00	0	0.00

Anexure 2

Weather data (monthly average) of Agricultural Research Station Mannuthy

Month	Temperature(oc)		Relative humidity	Rain fall	
	max.	min.	(%)	Rainy days	rainfall '(mm)
January	33.50	21.70	54.00	0	2.50
February	35.70	21.60	51.00	5	0.00
March	36.30	24.00	63.00	14	12.50
April	35.60	25.00	68.00	10	58.40
May	33.40	24.70	75.00	22	251.90
June	29.60	23.30	86.00	24	748.30
July	28.90	22.90	87.00	27	656.60
August	29.20	22.90	85.00	10	403.20
September	30.70	23.40	80.00	3	109.70
October	31.30	23.10	81.00	1	315.40
November	31.70	23.40	71.00	0	89.70
December	32.30	22.70	61.00	1	0.60

Anexure 3

Weather data (monthly average) of Coconut Research Station Balaramapuuram

Month	Temperature(oC) max.	min.	Relative humidity (%)	Rain fall Rainy days	Rainfall '(mm)
January	31.30	22.30	70.00	2	20.10
February	31.70	22.90	71.00	2	20.30
March	32.50	24.20	73.00	3	43.50
April	32.40	25.10	77.00	7	122.10
May	31.60	25.00	81.00	11	248.60
June	29.40	23.60	86.00	19	331.20
July	29.10	23.20	85.00	16	215.40
August	29.40	23.30	83.00	12	164.00
September	29.90	23.30	82.00	9	122.90
October	29.90	23.40	84.00	12	271.20
November	30.10	23.10	83.00	11	206.90
December	30.90	22.50	80.00	4	73.10

Anexure 4

Relevant data for development of DRIS norms for coconut palm

Form of expression	Low yield group (A)				High yield group (B)				Variance ratio (SA/SB)
	Mean	S D	Variance (SA)	C V (%)	Mean	S D	Variance (SB)	C V (%)	
N	1.680	0.369	0.136	21.96	1.520	0.258	0.067	16.97	2.04*
P	0.155	0.038	0.001	24.52	0.191	0.047	0.002	24.61	1.52*
K	1.340	0.336	0.113	25.07	1.240	0.308	0.095	24.82	1.190
Ca	0.309	0.087	0.008	28.16	0.245	0.067	0.005	27.35	1.68*
Mg	0.191	0.037	0.001	19.37	0.199	0.026	0.001	13.07	1.94*
S	0.124	0.054	0.003	43.54	0.176	0.057	0.003	33.29	1.100
Cl	0.627	0.100	0.010	15.95	0.638	0.079	0.006	12.38	1.62*
Fe	0.032	0.010	10.00$	31.25	0.029	0.010	9.00$	33.45	1.090
Zn	0.002	0.001	1.00$	23.81	0.002	0.001	0.90$	23.81	1.110
Mn	0.020	0.008	0.60$	37.50	0.022	0.008	0.50$	37.21	1.130
N/P	11.680	4.410	19.430	37.76	8.360	2.450	5.990	29.27	3.24*
N/K	1.340	0.494	0.244	36.87	1.320	0.480	0.228	36.24	1.070
N/Ca	5.830	2.020	4.060	34.65	6.610	1.900	3.620	28.79	1.120
N/Mg	9.230	3.320	11.020	35.97	7.680	1.340	1.790	17.42	6.15*
N/S	17.330	10.020	100.470	57.81	9.460	3.280	10.760	34.67	9.34*
N/Cl	2.740	0.780	0.600	28.47	2.430	0.600	0.354	24.53	1.69*
N/Fe	59.120	29.050	843.900	49.14	57.940	21.910	48.030	37.81	1.76*
N/Zn	832.100	249.600	6228.300	30.00	774.200	227.300	51644.600	29.35	1.210
N/Mn	96.020	38.450	1478.700	40.36	80.120	31.300	981.500	39.10	1.51*
P/N	0.100	0.042	0.002	42.00	0.127	0.028	0.001	22.13	2.19*
P/K	0.120	0.039	0.002	32.50	0.167	0.073	0.005	43.21	3.47*
P/Ca	0.530	0.162	0.026	30.57	0.837	0.282	0.080	33.74	3.03*
P/Mg	0.833	0.225	0.051	27.01	0.961	0.202	0.041	21.03	1.240
P/S	1.440	0.539	0.291	37.43	1.160	0.384	0.148	33.12	1.97*
P/Cl	0.254	0.079	0.006	31.10	0.306	0.093	0.009	30.33	1.340
P/Fe	5.250	2.370	5.620	45.14	7.410	3.360	11.280	45.32	2.00*
P/Zn	78.100	28.430	808.070	36.40	96.400	31.270	977.900	32.44	1.210
P/Mn	8.820	3.480	12.120	39.46	10.050	4.020	16.150	39.95	1.330
K/N	0.868	0.377	0.142	43.43	0.863	0.317	0.100	36.70	1.42*
K/P	9.180	3.210	10.310	32.72	7.200	3.300	10.910	45.86	1.060
K/Ca	4.780	2.150	4.630	44.98	5.530	2.300	5.300	41.63	1.140
K/Mg	7.340	2.440	5.930	33.27	6.450	2.080	4.330	32.30	1.370
K/S	12.990	5.890	34.660	45.34	8.110	3.860	15.090	47.91	2.30*
K/Cl	2.200	0.656	0.431	29.82	1.980	0.540	0.293	27.32	1.47*
K/Fe	45.870	19.070	363.540	41.57	49.560	26.710	713.200	53.89	1.96*
K/Zn	695.600	312.000	97362.000	44.82	645.900	244.500	59775.000	37.86	1.63*
K/Mn	81.720	45.800	2097.400	56.05	68.700	36.900	1364.300	53.78	1.54*

contd..

Form of expression	Low yield group (A)				High yield group (B)				Variance ratio (SA/SB)
	Mean	S D	Variance (SA)	C V (%)	Mean	S D	Variance (SB)	C V (%)	
Ca/N	0.195	0.078	0.006	40.00	0.168	0.064	0.004	38.31	1.45*
Ca/P	2.080	0.710	0.507	34.13	1.420	0.760	0.570	53.28	1.130
Ca/K	0.247	0.100	0.010	40.49	0.213	0.086	0.007	40.24	1.380
Ca/Mg	1.640	0.403	0.163	24.57	1.250	0.383	0.147	30.67	1.110
Ca/S	2.990	1.460	2.140	48.82	1.580	0.820	0.660	51.48	3.22*
Ca/Cl	0.508	0.176	0.031	34.65	0.390	0.121	0.015	31.02	2.13*
Ca/Fe	10.530	4.630	21.450	43.96	9.200	3.540	12.520	38.45	1.71*
Ca/Zn	155.800	62.900	3962.900	40.32	124.900	45.130	2037.500	36.14	1.95*
Ca/Mn	17.380	7.120	50.680	40.97	12.290	3.710	13.790	30.20	3.68*
Mg/N	0.121	0.039	0.002	32.23	0.134	0.025	0.001	18.94	2.42*
Mg/P	1.290	0.380	0.143	29.46	1.110	0.350	0.122	31.64	1.160
Mg/K	0.150	0.046	0.002	30.67	0.172	0.059	0.003	34.01	1.60*
Mg/Ca	0.647	0.162	0.026	25.04	0.862	0.208	0.044	24.25	1.67*
Mg/S	1.830	0.791	0.625	43.20	1.250	0.420	0.176	33.76	3.54*
Mg/Cl	0.313	0.081	0.007	25.88	0.317	0.060	0.004	18.99	1.82*
Mg/Fe	6.600	3.000	9.000	45.45	7.700	3.010	9.090	39.11	1.010
Mg/Zn	97.010	33.760	1139.500	34.80	101.850	28.700	823.500	28.18	1.380
Mg/Mn	11.150	4.800	22.950	43.05	10.530	3.880	15.100	36.88	1.52*
S/N	0.081	0.047	0.002	58.02	0.117	0.034	0.001	29.39	1.90*
S/P	0.799	0.332	0.110	55.00	0.936	0.250	0.063	26.71	1.76*
S/K	0.095	0.046	0.002	48.42	0.154	0.074	0.005	47.82	2.52*
S/Ca	0.422	0.210	0.044	49.76	0.764	0.290	0.084	37.97	1.91*
S/Mg	0.652	0.279	0.078	42.79	0.879	0.244	0.060	27.82	1.310
S/Cl	0.203	0.096	0.009	47.29	0.282	0.106	0.011	37.51	1.210
S/Fe	4.220	2.770	7.700	65.64	6.830	3.430	11.790	50.25	1.53*
S/Zn	63.330	33.360	1112.800	48.82	89.740	37.900	1438.600	42.26	1.300
S/Mn	7.020	3.710	13.750	52.84	9.200	4.040	16.320	43.91	1.190
Cl/N	0.396	0.120	0.014	30.30	0.437	0.112	0.013	25.56	1.150
Cl/P	4.310	1.320	1.740	30.56	3.630	1.380	1.920	38.05	1.81*
Cl/K	0.493	0.138	0.019	27.99	0.545	0.156	0.024	28.72	1.280
Cl/Ca	2.200	0.739	0.545	33.59	2.770	0.720	0.520	26.06	1.050
Cl/Mg	3.440	1.000	1.010	29.07	3.260	0.607	0.369	18.62	2.75*
Cl/S	6.240	3.040	9.240	48.72	4.100	1.700	2.900	41.48	3.19*
Cl/Fe	21.740	9.430	88.870	43.38	24.440	8.830	77.900	36.12	1.140
Cl/Zn	314.230	90.470	8185.200	28.79	326.300	88.100	7766.700	27.01	1.060
Cl/Mn	36.460	14.930	222.980	40.94	34.030	13.670	186.770	40.16	1.190

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Form of expression	Low yield group (A)				High yield group (B)				Variance ratio (SA/SB)
	Mean	S D	Variance (SA)	C V (%)	Mean	S D	Variance (SB)	C V (%)	
Fe/N	0.018	0.009	0.001	45.79	0.020	0.008	0.001	37.31	
Fe/P	0.218	0.074	0.006	33.94	0.166	0.082	0.007	49.40	1.220
Fe/K	0.026	0.010	10.00$	40.80	0.025	0.011	9.00$	44.50	1.230
Fe/Ca	0.113	0.047	0.002	41.59	0.124	0.046	0.002	37.02	1.080
Fe/Mg	0.177	0.067	0.005	37.85	0.150	0.059	0.004	39.45	1.280
Fe/S	0.313	0.154	0.024	49.20	0.190	0.109	0.012	57.60	1.97*
Fe/Cl	0.053	0.019	0.001	35.85	0.046	0.016	0.001	35.85	1.320
Fe/Zn	16.410	6.800	46.250	41.44	14.830	5.960	14.830	40.15	1.300
Fe/Mn	1.890	0.917	0.842	48.52	1.530	0.778	0.605	50.90	1.390
Zn/N	0.001	0.001	0.03$	38.46	0.001	0.001	0.03$	28.57	1.200
Zn/P	0.015	0.006	0.36$	40.00	0.012	0.004	0.18$	33.91	2.06*
Zn/K	0.002	0.001	0.05$	41.18	0.002	0.001	0.04$	44.44	1.210
Zn/Ca	0.007	0.003	0.30$	38.57	0.009	0.003	0.26$	32.20	1.160
Zn/Mg	0.012	0.005	0.22$	39.17	0.011	0.003	0.08$	27.36	2.54*
Zn/S	0.021	0.013	2.00$	61.90	0.013	0.006	0.40$	43.18	5.12*
Zn/Cl	0.004	0.001	0.10$	31.42	0.003	0.001	0.09$	27.27	1.290
Zn/Fe	0.074	0.035	0.001	47.30	0.079	0.037	0.001	46.80	1.150
Zn/Mn	0.120	0.050	0.003	41.67	0.108	0.042	0.002	38.61	1.44*
Mn/N	0.012	0.006	0.36$	49.17	0.014	0.006	0.32$	42.47	1.110
Mn/P	0.133	0.056	0.003	42.10	0.122	0.071	0.005	57.84	1.56*
Mn/K	0.016	0.008	10.00$	50.00	0.019	0.009	8.00$	49.70	1.380
Mn/Ca	0.066	0.024	0.001	36.36	0.089	0.025	0.001	28.80	1.110
Mn/Mg	0.108	0.052	0.003	48.15	0.110	0.046	0.002	41.36	1.320
Mn/S	0.194	0.115	0.013	59.30	0.137	0.076	0.006	55.40	2.30*
Mn/Cl	0.032	0.014	2.00$	43.75	0.034	0.014	2.00$	39.36	1.000
Mn/Fe	0.690	0.397	0.157	57.54	0.810	0.397	0.158	48.97	1.000
Mn/Zn	9.790	4.470	19.980	45.66	10.770	4.250	18.050	39.44	1.100

SD : Standard deviation

CV : Coefficient of variation

$: $x 10^{-4}$

* : Significant at 5% level

Anexure 5

Relevant data for DRIS norms for coconut palms using 80 nuts /palm /year as the yield cut-off value

Form of expression	Low yield group (A)				High yield group (B)				Variance ratio (SA/AB)
	Mean	S D	Variance (SA)	C V (%)	Mean	S D	Variance (SB)	C V (%)	
N	1.620	0.306	0.093	18.890	1.510	0.258	0.067	17.090	1.41*
P	0.151	0.045	0.002	29.800	0.191	0.047	0.002	24.610	1.100
K	1.270	0.275	0.075	21.650	1.230	0.308	0.095	25.040	1.240
Ca	0.303	0.089	0.008	29.370	0.246	0.067	0.005	27.240	1.70*
Mg	0.188	0.037	0.001	19.680	0.197	0.027	0.001	13.710	1.95*
S	0.131	0.063	0.004	48.090	0.176	0.057	0.003	32.390	1.220
Cl	0.627	0.097	0.009	15.470	0.638	0.079	0.006	12.380	1.50*
Fe	0.028	0.010	1.00$	35.000	0.029	0.010	1.00$	33.450	1.030
Zn	0.002	0.001	0.04$	26.080	0.002	0.001	0.74$	23.800	1.44*
Mn	0.022	0.008	0.001	37.270	0.022	0.008	0.001	36.360	1.050
N/P	11.950	4.470	19.990	37.410	8.530	2.400	5.740	28.470	3.48*
N/K	1.320	0.431	0.186	32.650	1.300	0.454	0.206	34.920	1.110
N/Ca	5.640	1.810	3.270	32.090	6.480	2.060	4.260	31.790	1.300
N/Mg	8.910	2.740	7.510	30.750	7.760	1.420	2.030	18.300	3.70*
N/S	15.420	7.920	62.730	51.360	9.820	3.350	11.230	34.110	5.58*
N/Cl	2.630	0.719	0.517	27.340	2.460	0.613	0.375	24.920	1.38*
N/Fe	66.170	35.770	1279.190	54.060	56.670	20.450	418.290	36.090	3.06*
N/Zn	757.670	255.200	65122.900	33.680	745.400	232.000	53837.300	31.140	1.210
N/Mn	82.460	33.490	1121.770	40.610	78.910	31.400	986.900	39.790	1.140
P/N	0.095	0.035	0.001	36.840	0.125	0.028	0.001	22.400	1.48*
P/K	0.121	0.053	0.003	43.800	0.162	0.069	0.005	42.590	1.73*
P/Ca	0.519	0.207	0.043	39.880	0.814	0.281	0.079	34.520	1.85*
P/Mg	0.795	0.222	0.049	27.920	0.947	0.196	0.038	20.700	1.290
P/S	1.290	0.470	0.218	36.430	1.180	0.387	0.150	32.800	1.45*
P/Cl	0.239	0.081	0.007	33.890	0.303	0.092	0.008	30.360	1.290
P/Fe	6.020	3.670	13.500	60.960	7.050	3.070	9.430	43.550	1.43*
P/Zn	68.370	28.710	824.300	41.990	90.350	31.890	1017.300	35.300	1.230
P/Mn	7.460	3.280	10.750	43.960	9.660	3.900	15.210	40.370	1.41*
K/N	0.845	0.294	0.086	34.790	0.863	0.302	0.091	34.990	1.060
K/P	9.820	3.750	14.060	38.180	7.510	3.390	11.460	45.130	1.230
K/Ca	4.610	1.830	3.350	39.690	5.430	2.310	5.340	42.540	1.60*
K/Mg	7.260	2.310	5.320	31.820	6.540	2.140	4.570	32.720	1.160
K/S	12.680	6.040	36.480	47.630	8.660	4.440	19.670	51.270	1.85*
K/Cl	2.190	0.560	0.317	25.570	1.990	0.530	0.286	26.630	1.110
K/Fe	51.800	23.720	562.500	45.790	47.920	23.750	564.230	49.560	1.000
K/Zn	617.770	251.180	63089.200	40.650	621.200	232.200	53928.000	37.380	1.170
K/Mn	69.190	37.230	1386.400	53.810	67.560	35.960	1293.000	53.230	1.070

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Anexure 5

Form of expression	Low yield group (A)				High yield group (B)				Variance ratio (SA/AB)
	Mean	S D	Variance (SA)	C V (%)	Mean	S D	Variance (SB)	C V (%)	
Ca/N	0.198	0.070	0.005	35.350	0.173	0.066	0.004	38.150	1.140
Ca/P	2.300	0.926	0.858	40.260	1.510	0.765	0.585	50.660	1.47*
Ca/K	0.251	0.098	0.010	39.040	0.217	0.089	0.008	41.010	1.200
Ca/Mg	1.670	0.460	0.212	27.540	1.290	0.382	0.146	29.610	1.45*
Ca/S	2.920	1.350	1.820	46.230	1.720	0.897	0.805	52.150	2.26*
Ca/Cl	0.507	0.181	0.033	35.700	0.405	0.138	0.019	34.070	1.72*
Ca/Fe	12.020	5.190	26.980	43.180	9.180	3.230	10.420	35.190	2.59*
Ca/Zn	145.460	63.970	4092.000	43.980	123.600	46.220	2136.600	37.390	1.92*
Ca/Mn	15.360	6.810	46.440	44.340	12.400	3.760	14.160	30.320	3.28*
Mg/N	0.121	0.034	0.001	28.100	0.134	0.027	0.001	20.150	1.65*
Mg/P	1.380	0.450	0.202	32.610	1.140	0.342	0.117	30.000	1.73*
Mg/K	0.153	0.052	0.003	33.990	0.170	0.058	0.003	34.120	1.210
Mg/Ca	0.644	0.175	0.031	61.160	0.833	0.209	0.044	25.090	1.43*
Mg/S	1.760	0.714	0.509	40.570	1.300	0.472	0.223	36.310	2.28*
Mg/Cl	0.308	0.082	0.007	26.620	0.315	0.063	0.004	20.000	1.66*
Mg/Fe	7.680	4.090	16.700	53.260	7.420	2.770	7.680	37.330	2.17*
Mg/Zn	89.300	34.070	1160.970	38.150	97.150	28.380	805.200	29.210	1.44*
Mg/Mn	9.720	4.430	19.650	45.580	10.230	3.720	13.890	36.360	1.41*
S/N	0.081	0.041	0.002	51.250	0.113	0.038	0.002	33.630	1.120
S/P	0.871	0.337	0.114	38.690	0.936	0.274	0.075	29.270	1.51*
S/K	0.103	0.064	0.004	49.230	0.149	0.077	0.006	51.680	1.48*
S/Ca	0.435	0.247	0.061	56.780	0.729	0.321	0.103	44.030	1.69*
S/Mg	0.670	0.283	0.081	42.230	0.863	0.285	0.081	33.020	1.010
S/Cl	0.204	0.098	0.010	48.030	0.273	0.108	0.012	39.560	1.210
S/Fe	5.370	4.560	20.830	84.910	6.470	3.630	13.150	56.110	1.58*
S/Zn	59.760	34.050	1159.100	56.970	84.190	38.630	1492.100	45.880	1.280
S/Mn	6.240	3.420	11.690	53.270	8.750	4.170	17.360	47.660	1.49*
Cl/N	0.403	0.106	0.011	26.300	0.436	0.107	0.012	24.540	1.040
Cl/P	4.690	1.530	2.330	32.620	3.730	1.310	1.720	35.120	1.36*
Cl/K	0.503	0.136	0.019	27.030	5.410	0.155	0.024	28.650	1.300
Cl/Ca	2.200	0.703	0.494	31.950	2.720	0.780	0.611	28.680	1.240
Cl/Mg	3.480	0.967	0.879	26.930	3.290	0.640	0.415	18.790	2.12*
Cl/S	6.060	2.740	7.530	45.210	4.300	1.820	3.300	42.330	2.28*
Cl/Fe	25.400	12.090	146.400	47.590	23.850	8.720	76.030	36.560	1.93*
Cl/Zn	294.500	96.300	9272.800	37.930	313.900	89.900	8096.600	28.630	1.150
Cl/Mn	32.400	13.850	191.900	42.750	33.400	13.420	179.900	40.180	1.070

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Anexure 5

Form of expression	Low yield group (A)				High yield group (B)				Variance ratio
	Mean	S D	Variance (SA)	C V (%)	Mean	S D	Variance (SB)	C V (%)	(SA/AB)
Fe/N	0.019	0.009	0.001	45.790	0.020	0.008	0.001	37.310	1.35*
Fe/P	0.215	0.092	0.009	42.790	0.173	0.078	0.006	45.090	1.41*
Fe/K	0.023	0.009	0.001	40.000	0.025	0.010	0.001	40.000	1.280
Fe/Ca	0.098	0.039	0.002	39.800	0.122	0.043	0.002	35.250	1.150
Fe/Mg	0.159	0.064	0.004	40.250	0.152	0.052	0.003	34.210	1.52*
Fe/S	0.279	0.144	0.021	51.610	0.200	0.106	0.011	53.000	1.83*
Fe/Cl	0.047	0.019	0.001	40.430	0.047	0.015	0.001	31.900	1.57*
Fe/Zn	13.430	6.360	40.440	47.360	14.410	5.600	31.320	38.860	1.290
Fe/Mn	1.500	0.837	0.700	55.800	1.520	0.717	0.515	47.170	1.36*
Zn/N	0.002	0.001	0.010$	33.330	0.002	0.40$	0.01$	26.670	1.42*
Zn/P	0.017	0.007	0.49$	41.180	0.013	0.005	0.25$	36.150	2.38*
Zn/K	0.002	0.001	0.05$	36.840	0.002	0.001	0.04$	42.110	1.100
Zn/Ca	0.008	0.003	0.90$	39.510	0.009	0.003	0.80$	34.780	1.020
Zn/Mg	0.013	0.005	0.25$	38.460	0.011	0.003	0.09$	28.180	2.74*
Zn/S	0.023	0.013	1.69$	56.520	0.015	0.007	0.49$	46.000	3.26*
Zn/Cl	0.004	0.001	0.010$	36.840	0.004	0.001	0.01$	31.430	1.64*
Zn/Fe	0.092	0.044	0.002	47.830	0.081	0.036	0.001	44.440	1.47*
Zn/Mn	0.117	0.053	0.003	45.300	0.111	0.046	0.002	41.440	1.300
Mn/N	0.014	0.006	0.001	42.140	0.015	0.006	0.001	41.330	1.130
Mn/P	0.164	0.074	0.006	45.120	0.128	0.068	0.005	53.130	1.200
Mn/K	0.018	0.009	0.001	50.560	0.019	0.009	0.001	49.470	1.070
Mn/Ca	0.075	0.026	0.001	34.670	0.088	0.026	0.001	29.540	1.040
Mn/Mg	0.124	0.055	0.003	44.350	0.112	0.044	0.002	39.280	1.58*
Mn/S	0.208	0.104	0.011	50.000	0.145	0.077	0.006	53.100	1.81*
Mn/Cl	0.037	0.016	0.001	43.240	0.035	0.015	0.001	42.860	1.240
Mn/Fe	0.917	0.578	0.334	63.030	0.801	0.364	0.133	44.930	2.52*
Mn/Zn	10.320	4.750	22.600	46.020	10.550	4.210	17.730	39.900	1.270

SD : Standard deviation
CV : Coefficient of variation
$: $\times 10^{-4}$
* : Significant at 5% level

Relevant data for DRIS norms for coconut palms using 60 nuts/palm/year as the yield cut-off value

Form of expression	Low yield group (A)				High yield group (B)				Variance ratio (SA/SB)
	Mean	S D	Variance (SA)	C V (%)	Mean	S D	Variance (SB)	C V (%)	
N	1.640	0.316	0.100	19.270	1.520	0.267	0.071	17.570	1.40*
P	0.141	0.040	0.002	28.370	0.174	0.049	0.002	28.160	1.55*
K	1.314	0.275	0.075	20.920	1.249	0.284	0.080	22.740	1.070
Ca	0.311	0.090	0.008	28.940	0.270	0.079	0.006	29.260	1.290
Mg	0.186	0.039	0.002	20.970	0.196	0.031	0.001	15.820	1.52*
S	0.117	0.051	0.003	43.590	0.163	0.069	0.005	42.330	1.85*
Cl	0.621	0.098	0.010	15.780	0.639	0.087	0.007	13.610	1.270
Fe	0.030	0.010	0.001	33.560	0.028	0.009	0.001	33.210	1.170
Zn	0.002	0.001	0.002	29.540	0.002	0.001	0.002	26.520	1.140
Mn	0.021	0.008	0.003	36.320	0.023	0.009	0.003	37.070	1.260
N/P	12.730	4.800	23.060	37.710	9.350	2.780	7.720	29.730	2.99*
N/K	1.320	0.428	0.183	32.420	1.300	0.448	0.201	34.460	1.100
N/Ca	5.670	1.800	3.260	31.750	6.130	2.030	4.110	33.120	1.260
N/Mg	9.260	2.960	8.740	31.970	7.930	1.700	2.900	21.440	3.01*
N/S	17.010	8.510	72.280	49.850	10.790	4.180	17.440	38.740	4.15*
N/Cl	2.730	0.770	0.592	26.210	2.430	0.567	0.322	23.330	1.84*
N/Fe	64.390	33.770	1140.300	52.450	63.460	32.310	1044.000	50.910	1.090
N/Zn	789.900	252.900	63943.000	32.020	712.900	237.500	56407.600	33.310	1.130
N/Mn	87.310	34.190	1169.300	39.160	74.680	30.070	903.900	42.380	1.290
P/N	0.090	0.035	0.001	38.890	0.116	0.031	0.001	26.720	1.210
P/K	0.113	0.042	0.002	37.170	0.152	0.070	0.005	46.050	2.81*
P/Ca	0.483	0.172	0.029	35.610	0.707	0.286	0.082	40.450	2.78*
P/Mg	0.777	0.221	0.049	28.310	0.893	0.215	0.046	24.080	1.060
P/S	1.342	0.472	0.223	35.270	1.180	0.411	0.169	34.830	1.32*
P/Cl	0.233	0.077	0.006	33.050	0.278	0.092	0.009	33.090	1.42*
P/Fe	5.430	3.140	9.850	57.830	7.220	3.790	14.380	52.490	1.46*
P/Zn	68.520	28.250	798.060	41.230	81.790	33.050	1092.500	40.400	1.37*
P/Mn	7.480	3.230	10.400	43.180	8.540	3.830	14.630	44.850	1.41*
K/N	0.843	0.299	0.089	35.470	0.858	0.292	0.085	34.030	1.050
K/P	10.130	3.760	14.130	37.120	8.030	3.520	12.360	43.830	1.140
K/Ca	4.620	1.850	3.430	40.040	5.100	2.160	4.670	42.350	1.36*
K/Mg	7.410	2.290	5.230	30.900	6.640	2.200	4.870	33.130	1.070
K/S	13.340	6.002	36.030	45.090	9.430	5.050	25.600	53.550	1.41*
K/Cl	2.170	0.579	0.335	26.680	1.990	0.516	0.267	25.930	1.260
K/Fe	49.680	21.370	456.700	43.020	51.830	26.260	689.500	50.690	1.51*
K/Zn	644.500	261.090	68169.800	40.530	589.090	223.500	49943.600	37.880	1.36*
K/Mn	72.810	35.060	1448.300	48.150	64.020	34.890	1217.200	50.150	1.190

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Anexure 6

Form of expression	Low yield group (A)				High yield group (B)				Variance ratio
	Mean	S D	Variance (SA)	C V (%)	Mean	S D	Variance (SB)	C V (%)	(SA/SB)
Ca/N	0.197	0.071	0.005	36.040	0.184	0.068	0.005	36.960	1.080
Ca/P	2.370	0.924	0.854	38.980	1.730	0.867	0.753	50.120	1.130
Ca/K	0.250	0.098	0.010	39.200	0.231	0.095	0.009	41.120	1.070
Ca/Mg	1.700	0.447	0.199	26.290	1.400	0.449	0.202	32.070	1.010
Ca/S	3.080	1.350	1.820	43.830	2.000	1.090	1.197	54.500	1.53*
Ca/Cl	0.518	0.188	0.036	36.290	0.431	0.148	0.022	34.340	1.62*
Ca/Fe	11.620	5.150	26.620	44.320	10.730	4.510	20.310	42.030	1.310
Ca/Zn	151.670	66.390	4407.700	48.430	124.810	48.430	2345.800	38.800	1.88*
Ca/Mn	16.210	7.020	49.340	43.310	12.580	4.470	20.020	35.530	2.46*
Mg/N	0.118	0.035	0.001	29.660	0.132	0.029	0.001	21.970	1.5*
Mg/P	1.410	0.461	0.212	32.700	1.205	0.378	0.143	31.400	1.48*
Mg/K	0.149	0.049	0.002	32.890	0.168	0.058	0.003	34.520	1.41*
Mg/Ca	0.628	0.160	0.026	25.500	0.779	0.218	0.048	27.980	1.87*
Mg/S	1.830	0.723	0.522	39.510	1.390	0.555	0.307	39.930	1.70*
Mg/Cl	0.309	0.085	0.007	27.510	0.312	0.066	0.004	21.150	1.66*
Mg/Fe	7.190	3.800	14.410	52.850	8.070	3.660	13.390	45.350	1.080
Mg/Zn	91.170	34.870	1216.060	38.250	91.980	30.080	904.900	32.700	1.34*
Mg/Mn	10.060	4.530	20.500	45.020	9.650	3.890	15.140	40.310	1.35*
S/N	0.075	0.038	0.002	50.670	0.107	0.041	0.002	38.310	1.130
S/P	0.843	0.325	0.105	38.550	0.943	0.310	0.096	32.870	1.090
S/K	0.094	0.047	0.002	50.000	0.143	0.083	0.007	58.040	3.13*
S/Ca	0.399	0.197	0.039	50.510	0.659	0.338	0.114	51.280	2.93*
S/Mg	0.636	0.255	0.065	40.090	0.829	0.308	0.095	37.150	1.47*
S/Cl	0.194	0.089	0.008	45.880	0.259	0.112	0.013	43.240	1.56*
S/Fe	4.660	3.740	14.020	80.250	6.860	4.680	21.880	68.220	1.56*
S/Zn	57.970	31.300	979.700	55.010	76.900	40.520	1641.900	51.970	1.68*
S/Mn	6.180	3.400	11.560	55.100	7.850	4.080	16.630	51.540	1.44*
Cl/N	0.394	0.106	0.011	26.900	0.434	0.104	0.011	23.960	1.040
Cl/P	4.760	1.560	2.430	32.770	4.010	1.390	1.940	34.660	1.250
Cl/K	0.492	0.127	0.016	25.810	0.540	0.156	0.024	28.890	1.52*
Cl/Ca	2.160	0.708	0.501	32.780	2.560	0.769	0.591	30.040	1.180
Cl/Mg	3.490	0.984	0.968	28.190	3.350	0.703	0.494	20.990	1.96*
Cl/S	6.320	2.820	7.940	44.620	4.670	2.080	4.340	44.540	1.83*
Cl/Fe	23.890	11.270	126.970	47.170	26.180	11.110	123.500	42.440	1.030
Cl/Zn	300.590	97.700	9545.500	32.500	299.400	91.600	8399.500	30.590	1.140
Cl/Mn	33.520	13.890	192.980	41.440	31.810	13.500	182.200	42.440	1.060

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Anexure 6

Form of expression	Low yield group (A)				High yield group (B)				Variance ratio (SA/SB).
	Mean	S D	Variance (SA)	C V (%)	Mean	S D	Variance (SB)	C V (%)	
Fe/N	0.019	0.009	0.81$	46.840	0.019	0.008	0.64$	40.000	1.37*
Fe/P	0.226	0.090	0.008	39.820	0.175	0.082	0.001	46.850	1.200
Fe/K	0.024	0.009	0.001	38.330	0.024	0.010	0.002	41.670	1.200
Fe/Ca	0.101	0.041	0.002	40.590	0.109	0.043	0.003	39.450	1.120
Fe/Mg	0.167	0.064	0.004	38.320	0.146	0.056	0.013	38.360	1.310
Fe/S	0.301	0.144	0.020	47.840	0.205	0.114	0.001	55.610	1.60*
Fe/Cl	0.050	0.019	3.60$	38.000	0.044	0.016	2.56$	36.820	1.47*
Fe/Zn	14.380	6.440	41.540	44.940	12.950	5.730	32.870	44.250	1.260
Fe/Mn	1.630	0.859	0.738	52.700	1.360	0.713	0.538	52.430	1.45*
Zn/N	0.001	0.001	0.03$	32.710	0.002	0.001	0.02$	31.250	1.010
Zn/P	0.017	0.007	0.05$	41.180	0.015	0.006	0.03$	40.000	1.33*
Zn/K	0.002	0.001	0.10$	38.890	0.002	0.001	0.08$	40.000	1.280
Zn/Ca	0.008	0.003	0.90$	42.310	0.009	0.003	0.80$	34.060	1.110
Zn/Mg	0.013	0.005	0.25$	40.000	0.012	0.004	1.06$	34.170	1.60*
Zn/S	0.023	0.013	1.70$	56.520	0.017	0.009	0.81$	53.520	2.08*
Zn/Cl	0.004	0.001	0.01$	37.840	0.004	0.001	0.01$	32.430	1.42*
Zn/Fe	0.085	0.041	0.002	48.240	0.094	0.043	0.002	45.740	1.090
Zn/Mn	0.119	0.054	0.003	45.350	0.111	0.047	0.002	42.340	1.32*
Mn/N	0.013	0.006	0.36$	42.310	0.016	0.006	0.34$	40.130	1.33*
Mn/P	0.161	0.073	0.005	45.340	0.146	0.075	0.006	51.370	1.050
Mn/K	0.017	0.008	0.64$	48.230	0.020	0.010	1.00$	49.500	1.49*
Mn/Ca	0.071	0.024	0.001	33.940	0.088	0.027	0.001	30.680	1.220
Mn/Mg	0.119	0.054	0.003	45.380	0.122	0.051	0.003	41.800	1.090
Mn/S	0.211	0.106	0.011	50.240	0.166	0.089	0.008	53.610	1.38*
Mn/Cl	0.035	0.016	0.001	44.570	0.037	0.016	0.001	43.240	1.070
Mn/Fe	0.827	0.518	0.269	62.640	0.949	0.532	0.284	56.060	1.060
Mn/Zn	10.200	4.860	23.600	47.650	10.600	4.280	18.380	40.380	1.280

S D : Standard deviation

C V : Coefficient of variation

$: $x 10^{-4}$

* : Significant at 5% level

Anexure 7

Relevant data for DRIS norms for coconut palm growing on laterite soil

Form of expression	Low yield group (A)				High yield group (B)				Variance ratio
	Mean	S D	Variance (SA)	C V (%)	Mean	S D	Variance (SB)	C V (%)	(SA/SB)
N	1.590	0.410	0.168	25.790	1.350	0.280	0.080	20.740	2.09*
P	0.153	0.035	0.001	22.850	0.143	0.043	0.002	30.070	1.530
K	1.450	0.360	0.127	24.830	1.300	0.190	0.036	14.620	3.51*
Ca	0.299	0.079	0.006	26.420	0.284	0.074	0.006	26.060	1.150
Mg	0.184	0.039	0.002	21.200	0.179	0.029	0.001	16.200	1.77*
S	0.120	0.054	0.003	45.000	0.122	0.037	0.001	30.330	2.10*
Cl	0.612	0.105	0.011	17.160	0.630	0.092	0.008	14.600	1.320
Fe	0.035	0.009	0.001	24.570	0.035	0.009	0.001	26.570	1.170
Zn	0.002	0.001	0.01$	30.000	0.002	4.00$	0.01$	22.000	1.82*
Mn	0.019	0.008	0.001	41.620	0.023	0.009	0.001	38.260	1.310
N/P	11.260	4.670	21.810	41.470	10.090	3.210	10.330	31.830	2.11*
N/K	1.180	0.465	0.216	39.410	1.070	0.310	0.097	29.080	2.23*
N/Ca	5.680	2.020	4.080	35.560	5.080	1.760	3.110	34.730	1.310
N/Mg	9.210	3.910	15.310	42.450	7.680	1.850	3.410	24.060	4.49*
N/S	17.520	10.910	111.030	62.200	11.780	3.520	12.390	29.870	9.61*
N/Cl	2.680	0.880	0.768	32.830	2.200	0.653	0.428	29.710	1.8*
N/Fe	49.800	21.260	451.800	42.690	41.050	11.930	142.540	29.090	3.17*
N/Zn	774.570	239.600	57393.900	30.930	699.510	205.300	42152.000	29.350	1.360
N/Mn	98.670	41.210	1697.900	41.770	67.800	30.870	953.200	45.500	1.78*
P/N	0.106	0.048	0.002	45.300	0.109	0.035	0.001	32.480	1.82*
P/K	0.111	0.036	0.001	32.430	0.114	0.043	0.002	37.720	1.450
P/Ca	0.540	0.157	0.025	29.070	0.540	0.202	0.041	37.600	1.65*
P/Mg	0.860	0.240	0.056	27.910	0.812	0.240	0.058	29.668	1.030
P/S	1.460	0.524	0.275	35.890	1.260	0.510	0.259	40.510	1.060
P/Cl	0.258	0.081	0.007	31.400	0.231	0.074	0.006	32.080	1.190
P/Fe	4.550	1.080	1.160	23.740	4.210	0.970	0.950	23.070	1.230
P/Zn	76.800	29.110	847.800	37.910	73.300	23.420	548.400	31.950	1.550
P/Mn	9.420	3.660	13.350	38.850	7.200	3.310	10.980	46.550	1.220
K/N	0.990	0.420	0.177	42.420	1.010	0.288	0.083	28.430	2.14*
K/P	9.970	3.420	11.700	34.300	9.960	3.470	12.040	34.850	1.030
K/Ca	5.300	2.310	5.320	43.580	4.990	1.920	3.670	38.410	1.450
K/Mg	8.230	2.620	6.880	31.830	7.520	2.030	4.140	27.070	1.66*
K/S	14.470	6.280	39.460	43.610	11.620	3.940	15.520	33.920	2.54*
K/Cl	2.420	0.695	0.483	28.720	2.100	0.422	0.178	20.130	2.71*
K/Fe	44.010	14.880	221.390	33.810	40.480	13.370	178.860	33.040	1.240
K/Zn	751.750	356.900	127351.000	47.470	679.700	195.300	38131.000	28.730	3.34*
K/Mn	94.630	49.720	2472.000	52.540	67.550	33.910	1149.700	50.200	2.14*

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Anexure 7

Form of expression	Low yield group (A)				High yield group (B)				Variance ratio (SA/SB)
	Mean	S D	Variance (SA)	C V (%)	Mean	S D	Variance (SB)	C V (%)	
Ca/N	0.204	0.087	0.008	42.650	0.220	0.075	0.006	34.090	1.330
Ca/P	2.030	0.600	0.359	29.560	2.160	0.860	0.740	39.760	2.05*
Ca/K	0.223	0.089	0.008	39.910	0.227	0.076	0.006	33.390	1.380
Ca/Mg	1.660	0.430	0.184	25.910	1.600	0.384	0.147	24.030	1.250
Ca/S	3.030	1.490	2.220	49.170	2.520	0.920	0.850	36.700	2.90*
Ca/Cl	0.510	0.168	0.028	32.940	0.462	0.153	0.024	33.200	1.200
Ca/Fe	9.100	3.060	9.340	33.630	8.900	3.600	13.060	40.630	1.400
Ca/Zn	148.540	57.370	3291.800	38.630	146.900	46.860	2195.800	31.890	1.500
Ca/Mn	18.270	7.680	59.120	42.030	13.550	4.410	19.470	32.550	3.04*
Mg/N	0.126	0.046	0.002	36.510	0.138	0.035	0.001	25.290	1.77*
Mg/P	1.260	0.361	0.130	28.650	1.360	0.211	0.460	33.900	1.63*
Mg/K	0.135	0.046	0.002	34.070	0.143	0.038	0.002	26.300	1.510
Mg/Ca	0.642	0.164	0.027	25.550	0.663	0.163	0.026	24.530	1.020
Mg/S	1.840	0.841	0.708	45.710	1.590	0.520	0.271	32.670	2.61*
Mg/Cl	0.311	0.090	0.008	28.940	0.289	0.060	0.004	20.730	2.26*
Mg/Fe	5.580	1.680	2.820	30.110	5.510	1.680	2.840	30.540	1.010
Mg/Zn	92.950	35.400	1253.200	38.180	93.000	24.400	595.440	26.240	2.1*
Mg/Mn	11.760	5.250	27.560	44.640	9.010	3.810	14.540	42.320	1.90*
S/N	0.087	0.056	0.003	64.370	0.093	0.029	0.001	31.180	3.69*
S/P	0.766	0.240	0.056	31.330	0.910	0.315	0.099	34.670	1.75*
S/K	0.085	0.041	0.002	48.240	0.096	0.036	0.001	36.700	1.290
S/Ca	0.425	0.225	0.051	52.940	0.458	0.180	0.034	40.150	1.490
S/Mg	0.662	0.295	0.088	44.560	0.698	0.232	0.054	33.400	1.61*
S/Cl	0.204	0.104	0.011	50.980	0.197	0.062	0.004	31.220	2.84*
S/Fe	3.420	1.210	1.460	35.380	3.660	1.080	1.170	29.500	1.250
S/Zn	62.090	35.260	1243.090	56.790	63.440	22.870	523.200	36.060	2.38*
S/Mn	7.450	4.110	16.910	55.170	6.120	3.100	9.630	50.730	1.76*
Cl/N	0.416	0.144	0.021	34.610	0.492	0.137	0.019	27.870	1.090
Cl/P	4.230	1.260	1.590	29.790	4.760	1.490	2.220	31.300	1.400
Cl/K	0.440	0.121	0.015	27.500	0.496	0.095	0.009	19.090	1.530
Cl/Ca	2.210	0.763	0.582	34.520	2.370	0.730	0.530	30.580	1.100
Cl/Mg	3.500	1.090	1.180	31.140	3.590	0.700	0.480	19.370	2.45*
Cl/S	6.330	3.090	9.530	48.820	5.590	1.770	3.140	31.700	3.03*
Cl/Fe	18.630	5.580	31.160	29.950	19.380	5.480	30.120	28.300	1.030
Cl/Zn	303.960	94.400	8910.900	31.060	327.900	83.600	6996.600	25.510	1.270
Cl/Mn	38.610	16.180	261.900	41.910	32.200	14.750	217.600	45.800	1.200

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Anexure 7

Form of expression	Low yield group (A)				High yield group (B)				Variance ratio (SA/SB)
	Mean	S D	Variance (SA)	C V (%)	Mean	S D	Variance (SB)	C V (%)	
Fe/N	0.024	0.010	0.001	42.920	0.027	0.008	0.001	29.810	1.72*
Fe/P	0.234	0.063	0.004	26.920	0.252	0.072	0.005	28.410	1.300
Fe/K	0.025	0.008	0.001	32.000	0.027	0.009	0.001	33.330	1.230
Fe/Ca	0.125	0.049	0.002	39.200	0.132	0.055	0.003	41.740	1.270
Fe/Mg	0.196	0.061	0.004	31.120	0.197	0.055	0.003	27.970	1.220
Fe/S	0.334	0.129	0.016	38.620	0.302	0.109	0.012	35.960	1.420
Fe/Cl	0.058	0.017	0.001	28.450	0.056	0.016	0.001	28.500	1.070
Fe/Zn	17.460	6.690	44.760	38.320	17.930	5.830	33.990	32.520	1.320
Fe/Mn	2.170	0.930	0.868	42.860	1.780	0.970	0.942	54.400	1.090
Zn/N	0.001	0.001	0.03$	35.710	0.002	0.001	0.02$	31.250	1.410
Zn/P	0.015	0.006	0.04$	37.500	0.015	0.005	0.03$	33.110	1.430
Zn/K	0.002	0.001	0.05$	43.750	0.002	0.001	0.04$	31.300	2.48*
Zn/Ca	0.008	0.003	0.80$	35.060	0.008	0.002	0.70$	32.000	1.230
Zn/Mg	0.013	0.005	0.25$	39.230	0.012	0.003	0.09$	25.220	2.99*
Zn/S	0.023	0.014	1.96$	60.860	0.018	0.007	0.49$	37.400	4.55*
Zn/Cl	0.004	0.001	0.01$	30.000	0.003	0.001	0.01$	27.300	1.60*
Zn/Fe	0.067	0.026	0.001	38.800	0.062	0.020	0.001	32.400	1.81*
Zn/Mn	0.132	0.054	0.003	40.910	0.100	0.043	0.002	43.600	1.490
Mn/N	0.013	0.007	0.001	53.850	0.018	0.007	0.001	41.800	1.110
Mn/P	0.126	0.058	0.003	46.030	0.173	0.084	0.007	48.800	2.17*
Mn/K	0.014	0.008	0.001	54.290	0.019	0.009	0.001	47.800	1.370
Mn/Ca	0.064	0.025	0.001	39.060	0.083	0.029	0.001	36.010	1.460
Mn/Mg	0.108	0.061	0.004	56.480	0.131	0.054	0.003	40.850	1.290
Mn/S	0.190	0.121	0.015	63.600	0.202	0.087	0.008	43.280	1.93*
Mn/Cl	0.031	0.015	0.001	48.390	0.038	0.017	0.001	44.300	1.310
Mn/Fe	0.563	0.276	0.077	49.020	0.717	0.335	0.112	46.740	1.460
Mn/Zn	9.020	4.400	19.350	48.780	11.750	4.540	20.650	38.660	1.070

S D : Standard deviation
C V : Coefficient of variation
$: x 10^{-4}
* : Significant at 5% level

Relevant data for DRIS norms for coconut palm growing on red sandy loam soil at Balaramapuram

Form of expression	Low yield group (A)				High yield group (B)				Variance ratio (SA/SB)
	Mean	S D	Variance (SA)	C V (%)	Mean	S D	Variance (SB)	C V (%)	
N	1.820	0.184	0.034	10.110	1.480	0.203	0.041	13.720	1.220
P	0.161	0.040	0.002	24.840	0.204	0.032	0.001	15.670	1.580
K	1.200	0.186	0.035	15.500	1.330	0.402	0.162	30.230	4.68*
Ca	0.316	0.072	0.005	22.500	0.213	0.044	0.002	20.660	2.73*
Mg	0.204	0.020	0.001	9.800	0.207	0.018	0.001	8.700	1.250
S	0.166	0.045	0.002	27.110	0.185	0.038	0.002	20.540	1.380
Cl	0.641	0.074	0.006	11.540	0.636	0.063	0.004	9.910	1.400
Fe	0.020	0.006	0.001	28.430	0.023	0.006	0.001	24.890	1.060
Zn	0.002	0.001	0.001	23.330	0.002	0.001	0.001	27.140	1.350
Mn	0.024	0.006	0.001	23.750	0.019	0.007	0.001	34.210	1.300
N/P	12.160	3.710	13.730	30.510	7.360	1.003	1.007	13.640	13.63*
N/K	1.560	0.312	0.097	20.000	1.260	0.494	0.244	39.210	2.51*
N/Ca	6.030	1.470	2.160	24.380	7.130	1.370	1.880	19.220	1.150
N/Mg	9.030	1.310	1.710	14.510	7.200	1.050	1.110	14.630	1.540
N/S	11.660	3.000	9.030	25.730	8.250	1.840	3.390	22.310	2.66*
N/Cl	2.880	0.440	0.200	15.230	2.370	0.456	0.308	19.290	1.070
N/Fe	101.800	37.200	1384.150	36.540	68.640	21.500	462.300	31.300	2.99*
N/Zn	921.300	220.800	48762.900	23.970	746.800	215.200	46293.500	28.810	1.050
N/Mn	88.710	22.290	496.700	25.130	84.300	25.300	641.700	30.080	1.290
P/N	0.089	0.024	0.001	26.970	0.138	0.019	0.001	13.480	1.700
P/K	0.136	0.033	0.001	24.260	0.175	0.074	0.006	42.400	5.03*
P/Ca	0.541	0.195	0.038	36.040	0.982	0.216	0.047	21.980	1.220
P/Mg	0.803	0.233	0.054	29.020	0.988	0.147	0.022	14.920	2.50*
P/S	1.050	0.400	0.159	38.100	1.130	0.230	0.055	20.690	2.92*
P/Cl	0.254	0.068	0.005	26.770	0.326	0.069	0.005	21.100	1.010
P/Fe	8.960	3.720	13.860	41.520	9.420	2.950	8.720	31.360	1.590
P/Zn	79.990	23.490	551.700	29.370	102.110	28.740	826.010	28.150	1.500
P/Mn	7.120	2.290	5.270	32.160	11.600	3.500	12.280	30.200	1.730
K/N	0.670	0.128	0.016	19.100	0.930	0.383	0.147	41.220	9.0*
K/P	7.880	2.160	4.660	27.410	6.820	2.880	8.280	42.160	1.78*
K/Ca	3.970	1.050	1.100	26.450	6.600	2.840	8.070	43.050	7.32*
K/Mg	5.960	1.190	1.400	19.970	6.520	2.330	5.440	35.770	3.88*
K/S	7.690	2.170	4.720	28.220	7.750	3.770	14.250	48.700	3.02*
K/Cl	1.890	0.342	0.117	18.100	2.090	0.631	0.399	30.210	3.42*
K/Fe	66.350	21.640	468.240	32.610	63.280	31.020	962.400	49.020	2.06*
K/Zn	603.400	148.400	22035.500	24.590	664.800	258.200	66679.900	38.840	3.03*
K/Mn	53.570	15.240	232.170	28.450	79.960	43.050	1853.410	53.840	7.98*

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Anexure 8

Form of expression	Low yield group (A)				High yield group (B)				Variance ratio (SA/SB)
	Mean	S D	Variance (SA)	C V (%)	Mean	S D	Variance (SB)	C V (%)	
Ca/N	0.175	0.041	0.002	23.430	0.146	0.029	0.001	20.040	1.98*
Ca/P	2.160	0.985	0.969	45.600	1.070	0.225	0.051	21.160	19.07*
Ca/K	0.270	0.075	0.006	27.780	0.183	0.081	0.007	44.100	1.150
Ca/Mg	1.550	0.291	0.085	18.770	1.030	0.168	0.028	16.320	2.99*
Ca/S	2.020	0.626	0.392	30.990	1.180	0.250	0.064	21.440	6.16*
Ca/Cl	0.501	0.134	0.018	26.750	0.343	0.990	0.009	28.780	1.84*
Ca/Fe	17.470	6.500	42.280	37.210	9.800	3.300	10.910	33.700	3.88*
Ca/Zn	162.310	62.650	3924.600	38.600	106.510	31.400	988.000	29.510	3.97*
Ca/Mn	14.150	4.930	24.260	24.260	11.940	3.250	10.570	27.220	2.30*
Mg/N	0.113	0.016	0.001	14.160	0.142	0.021	0.001	14.930	1.680
Mg/P	1.370	0.470	0.222	34.310	1.030	0.156	0.024	15.140	9.16*
Mg/K	0.175	0.037	0.001	21.140	0.175	0.066	0.004	37.770	3.13*
Mg/Ca	0.668	0.132	0.020	19.760	0.993	0.139	0.091	13.990	1.100
Mg/S	1.310	0.334	0.111	25.500	1.150	0.209	0.043	18.190	2.54*
Mg/Cl	0.320	0.056	0.003	17.500	0.329	0.047	0.002	14.223	1.460
Mg/Fe	11.330	4.000	16.000	35.300	9.510	2.500	6.220	26.220	2.57*
Mg/Zn	104.020	29.420	865.700	28.230	104.160	27.520	757.300	26.420	1.140
Mg/Mn	9.120	2.430	5.890	26.640	11.880	3.650	13.360	30.760	1.570
S/N	0.091	0.023	0.001	25.270	0.127	0.026	0.001	20.470	1.240
S/P	1.120	0.490	0.242	43.750	0.924	0.203	0.041	22.000	5.85*
S/K	0.142	0.046	0.002	32.390	0.161	0.074	0.006	45.900	2.63*
S/Ca	0.546	0.177	0.031	32.420	0.886	0.184	0.034	20.810	1.090
S/Mg	0.820	0.230	0.053	28.050	0.897	0.154	0.024	17.230	2.23*
S/Cl	0.263	0.080	0.006	30.420	0.297	0.073	0.005	24.410	1.220
S/Fe	9.290	4.240	17.980	45.640	8.340	1.810	3.270	21.690	5.50*
S/Zn	83.250	27.060	732.300	32.500	94.170	32.130	1032.330	34.120	1.410
S/Mn	7.400	2.620	6.860	13.450	10.580	3.420	11.680	32.320	1.700
Cl/N	0.350	0.047	0.002	13.430	0.440	0.085	0.007	19.490	3.27*
Cl/P	4.260	1.290	1.660	30.280	3.200	0.640	0.409	20.010	4.08*
Cl/K	0.545	0.099	0.010	18.170	0.528	0.032	0.179	34.030	3.23*
Cl/Ca	2.120	0.470	0.220	22.170	3.080	0.640	0.413	20.860	1.87*
Cl/Mg	3.170	0.490	0.248	15.450	3.090	0.367	0.135	11.890	1.84*
Cl/S	4.130	1.190	1.430	28.810	3.570	0.880	0.780	24.740	1.84*
Cl/Fe	35.510	12.030	144.820	33.880	29.410	8.390	70.390	28.530	2.06*
Cl/Zn	322.700	75.700	5733.660	23.466	318.840	83.590	6988.170	26.220	1.220
Cl/Mn	28.530	6.890	47.490	24.150	36.810	12.650	160.080	34.350	3.37*

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Anexure 8

Form of expression	Low yield group (A)				High yield group (B)				Variance ratio
	Mean	S D	Variance (SA)	C V (%)	Mean	S D	Variance (SB)	C V (%)	(SA/SB)
Fe/N	0.011	0.003	0.001	30.910	0.016	0.004	0.001	27.220	1.550
Fe/P	0.132	0.059	0.003	49.160	0.115	0.033	0.001	28.520	3.18*
Fe/K	0.017	0.006	0.36$	35.290	0.019	0.009	0.81$	45.690	2.10*
Fe/Ca	0.065	0.024	0.001	36.920	0.110	0.028	0.001	25.640	1.360
Fe/Mg	0.097	0.028	0.001	28.870	0.111	0.025	0.001	22.750	1.220
Fe/S	0.127	0.046	0.002	36.220	0.125	0.025	0.001	20.080	3.37*
Fe/Cl	0.030	0.001	0.001	30.000	0.037	0.011	0.001	29.730	1.310
Fe/Zn	10.040	3.900	15.220	38.840	11.620	4.170	17.380	35.870	1.140
Fe/Mn	0.880	0.330	0.109	37.500	1.310	0.441	0.194	33.680	1.78*
Zn/N	0.001	3.00$	0.001$	25.000	0.002	0.001	0.08$	33.330	2.45*
Zn/P	0.014	0.004	0.16$	27.860	0.011	0.003	0.010$	29.250	1.550
Zn/K	0.002	0.001	0.03$	27.780	0.002	0.001	0.02$	44.440	2.94*
Zn/Ca	0.007	0.002	0.08$	34.290	0.010	0.003	0.07$	28.430	1.540
Zn/Mg	0.010	0.003	0.09$	29.000	0.010	0.003	0.08$	29.810	1.150
Zn/S	0.013	0.004	0.02$	32.310	0.012	0.005	0.014$	37.500	1.160
Zn/Cl	0.003	0.001	0.06$	24.240	0.003	0.001	0.045$	29.410	1.620
Zn/Fe	0.116	0.050	0.003	43.100	0.099	0.044	0.002	44.850	1.270
Zn/Mn	0.093	0.031	0.001	33.330	0.119	0.040	0.002	33.780	1.680
Mn/N	0.013	0.004	0.001	27.690	0.013	0.004	0.001	29.460	1.090
Mn/P	0.156	0.054	0.003	34.620	0.095	0.033	0.001	34.320	2.75*
Mn/K	0.020	0.006	0.034$	28.710	0.016	0.009	0.017$	53.290	2.37*
Mn/Ca	0.078	0.023	0.001	29.490	0.089	0.024	0.001	26.420	1.020
Mn/Mg	0.117	0.031	0.001	26.500	0.093	0.033	0.001	35.740	1.130
Mn/S	0.152	0.052	0.003	34.210	0.106	0.043	0.002	40.560	1.460
Mn/Cl	0.037	0.011	1.00$	29.730	0.031	0.012	0.90$	38.110	1.200
Mn/Fe	1.320	0.560	0.320	42.420	0.890	0.450	0.201	50.610	1.580
Mn/Zn	12.060	4.440	19.720	36.810	9.360	3.090	9.550	33.050	2.07*

SD : Standard deviation

CV : Coefficient of variation

$: $x\ 10^{-4}$

* : Significant at 5% level

Anexure 9

Relevant data for DRIS norms for coconut palm growing on laterite soil at Pilicode

Form of expression	Low yield group (A)				High yield group (B)				Variance ratio (SA/SB)
	Mean	S D	Variance (SA)	C V (%)	Mean	S D	Variance (SA)	C V (%)	
N	1.890	0.290	0.084	15.340	1.270	0.254	0.065	19.940	1.300
P	0.127	0.023	0.001	18.100	0.118	0.013	0.001	11.020	3.11*
K	1.103	0.215	0.046	19.490	1.358	0.190	0.036	13.900	1.280
Ca	0.298	0.080	0.006	26.840	0.283	0.082	0.007	28.980	1.040
Mg	0.171	0.043	0.002	25.150	0.167	0.029	0.001	17.370	2.20*
S	0.065	0.010	0.001	13.850	0.109	0.023	0.001	21.100	5.23*
Cl	0.627	0.109	0.012	17.460	0.612	0.084	0.007	13.730	1.690
Fe	0.031	0.008	0.64$	25.810	0.028	0.005	0.25$	17.860	2.14*
Zn	0.002	0.001	0.07$	20.830	0.002	0.001	0.06$	20.000	1.510
Mn	0.020	0.007	0.04$	34.340	0.023	0.008	0.03$	34.780	1.500
N/P	15.340	3.690	13.650	24.050	11.000	2.640	6.950	23.970	1.96*
N/K	1.770	0.407	0.166	26.530	0.950	0.220	0.048	23.040	3.43*
N/Ca	6.750	2.000	3.990	29.630	4.940	2.040	4.149	41.250	1.030
N/Mg	11.770	3.770	14.210	32.030	7.870	2.270	5.174	28.910	2.75*
N/S	29.340	5.460	29.810	18.610	12.290	4.010	16.110	32.670	1.85*
N/Cl	3.100	0.719	0.516	23.190	2.140	0.620	0.386	28.990	1.340
N/Fe	64.420	16.170	261.550	25.100	47.920	13.880	192.550	28.960	1.360
N/Zn	817.620	215.190	46307.400	26.330	648.980	164.420	27034.120	25.340	1.72*
N/Mn	107.190	43.260	1871.470	40.350	62.980	28.830	831.330	45.780	2.25*
P/N	0.069	0.018	0.001	26.100	0.097	0.025	0.001	26.080	1.93*
P/K	0.120	0.034	0.001	28.330	0.089	0.017	2.89$	18.990	3.99*
P/Ca	0.453	0.127	0.016	28.040	0.456	0.159	0.025	34.890	1.570
P/Mg	0.787	0.223	0.050	28.340	0.724	0.148	0.022	20.470	2.27*
P/S	1.980	0.414	0.172	20.910	1.117	0.217	0.047	19.430	3.65*
P/Cl	0.209	0.052	0.003	24.760	0.196	0.036	0.001	18.160	2.15*
P/Fe	4.370	1.250	1.550	28.610	4.364	0.735	0.540	16.840	2.83*
P/Zn	55.070	14.790	218.830	26.860	60.590	13.753	189.140	22.700	1.160
P/Mn	7.210	2.850	8.100	39.530	5.776	2.179	4.750	37.730	1.710
K/N	0.596	0.140	0.020	23.330	1.108	0.273	0.074	24.600	3.81*
K/P	8.943	2.330	5.410	26.100	11.695	2.166	4.690	18.520	1.150
K/Ca	3.997	1.420	2.030	35.500	5.404	2.385	5.687	44.130	2.81*
K/Mg	6.940	2.510	6.290	36.170	8.429	2.195	4.817	26.040	1.310
K/S	17.270	4.163	17.330	24.110	13.120	3.889	15.122	29.640	1.150
K/Cl	1.805	0.432	0.187	23.870	2.258	0.422	0.178	18.700	1.050
K/Fe	38.480	13.610	185.190	35.370	50.445	10.458	109.370	20.730	1.690
K/Zn	478.460	130.940	17146.500	27.370	699.210	175.540	30812.900	25.110	1.80*
K/Mn	63.590	30.250	915.150	47.560	69.380	34.020	1157.430	49.040	1.260

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Anexure 9

Form of expression	Low yield group (A)				High yield group (B)				Variance ratio
	Mean	S D	Variance (SA)	C V (%)	Mean	S D	Variance (SA)	C V (%)	(SA/SB)
Ca/N	0.162	0.049	0.002	30.630	0.230	0.079	0.006	34.480	2.60*
Ca/P	2.420	0.879	0.772	36.320	2.430	0.736	0.542	30.290	1.430
Ca/K	0.286	0.119	0.014	41.610	0.217	0.081	0.007	37.280	2.16*
Ca/Mg	1.781	0.404	0.163	22.680	1.700	0.439	0.193	25.850	1.180
Ca/S	4.590	1.125	1.267	24.460	2.640	0.723	0.522	27.410	2.43*
Ca/Cl	0.494	0.179	0.032	36.230	0.474	0.171	0.029	36.140	1.090
Ca/Fe	10.087	2.850	8.140	28.220	10.550	3.498	12.233	33.140	1.500
Ca/Zn	131.080	54.640	2985.270	41.710	145.357	50.882	2588.960	35.010	1.150
Ca/Mn	16.560	6.590	43.450	39.790	12.968	3.455	11.933	26.640	3.64*
Mg/N	0.093	0.029	0.001	31.180	0.137	0.038	0.001	27.740	1.77*
Mg/P	1.393	0.490	0.240	32.250	1.441	0.301	0.091	20.870	2.66*
Mg/K	0.164	0.060	0.004	37.500	0.127	0.034	0.001	27.000	3.09*
Mg/Ca	0.591	0.137	0.019	23.220	0.634	0.192	0.037	30.300	1.96*
Mg/S	2.658	0.672	0.452	25.260	1.602	0.413	0.170	25.760	2.65*
Mg/Cl	0.282	0.087	0.008	30.850	0.279	0.064	0.004	23.050	1.83*
Mg/Fe	5.810	1.689	2.855	29.100	6.256	1.579	2.494	25.250	1.140
Mg/Zn	74.907	27.060	732.280	36.130	86.019	23.010	529.370	26.750	1.380
Mg/Mn	9.956	4.860	23.680	49.000	8.247	3.340	11.155	40.490	2.12*
S/N	0.035	0.008	0.64$	22.860	0.089	0.027	0.001	31.230	12.58*
S/P	0.532	0.144	0.021	27.060	0.928	0.175	0.031	18.850	1.470
S/K	0.062	0.020	0.001	32.260	0.082	0.021	0.001	26.100	1.120
S/Ca	0.232	0.064	0.004	27.590	0.410	0.120	0.014	29.220	3.52*
S/Mg	0.406	0.128	0.016	55.170	0.670	0.193	0.037	28.810	2.26*
S/Cl	0.108	0.026	0.001	24.070	0.182	0.047	0.002	25.600	3.32*
S/Fe	2.220	0.473	0.223	21.310	4.036	0.940	0.884	23.300	3.96*
S/Zn	28.397	7.645	58.446	26.940	56.779	18.950	359.090	33.370	6.14*
S/Mn	3.704	1.408	1.982	38.010	5.185	1.609	2.590	31.040	1.310
Cl/N	0.340	0.083	0.007	24.410	0.504	0.142	0.020	28.100	2.95*
Cl/P	5.070	1.201	1.443	23.680	5.254	0.889	0.791	16.930	1.82*
Cl/K	0.589	0.155	0.024	26.320	0.458	0.085	0.007	18.560	3.34*
Cl/Ca	2.253	0.722	0.521	32.090	2.375	0.855	0.730	35.980	1.400
Cl/Mg	3.897	1.227	1.505	31.540	3.756	0.817	0.668	21.760	2.25*
Cl/S	9.750	1.989	3.958	20.400	5.864	1.496	2.237	25.510	1.77*
Cl/Fe	21.529	6.263	39.222	29.080	22.795	4.759	22.649	20.880	1.730
Cl/Zn	270.170	66.170	4378.030	24.500	314.760	77.214	5961.950	24.530	1.360
Cl/Mn	36.060	15.237	232.180	42.270	30.389	12.664	160.373	41.670	1.450

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Anexure 9

Form of expression	Low yield group (A)				High yield group (B)				Variance ratio (SA/SB)
	Mean	S D	Variance (SA)	C V (%)	Mean	S D	Variance (SA)	C V (%)	
Fe/N	0.017	0.004	0.16$	23.530	0.023	0.008	0.64$	32.610	2.66*
Fe/P	0.249	0.078	0.006	31.200	0.236	0.043	0.002	18.390	3.23*
Fe/K	0.029	0.011	1.21$	37.930	0.021	0.004	0.16$	19.050	7.44*
Fe/Ca	0.109	0.038	0.002	34.860	0.108	0.046	0.002	42.220	1.440
Fe/Mg	0.189	0.065	0.004	34.390	0.170	0.044	0.002	25.770	2.17*
Fe/S	0.474	0.116	0.014	24.420	0.264	0.078	0.006	29.550	2.23*
Fe/Cl	0.051	0.015	0.002	29.410	0.046	0.012	0.001	25.220	1.570
Fe/Zn	13.390	4.810	23.090	35.900	14.269	4.279	18.307	29.990	1.260
Fe/Mn	1.719	0.628	0.395	36.510	1.364	0.623	0.389	45.700	1.020
Zn/N	0.001	0.001	0.06$	23.080	0.002	0.001	0.05$	25.000	1.370
Zn/P	0.020	0.005	0.04$	27.180	0.018	0.005	0.03$	26.270	1.302
Zn/K	0.002	0.001	0.01$	30.430	0.002	0.001	0.004$	26.670	3.26*
Zn/Ca	0.009	0.003	0.001	31.400	0.008	0.003	0.001	29.240	1.250
Zn/Mg	0.020	0.010	1.00$	50.000	0.010	0.012	0.003	25.000	2.48*
Zn/S	0.037	0.008	0.001	21.620	0.020	0.007	0.001	34.010	1.640
Zn/Cl	0.004	0.001	0.001	28.210	0.003	0.001	0.001	26.470	1.370
Zn/Fe	0.083	0.025	0.001	36.990	0.076	0.022	0.001	28.460	1.320
Zn/Mn	0.137	0.003	0.057	21.890	0.100	0.046	0.002	45.920	1.490
Mn/N	0.011	0.004	0.16$	37.380	0.019	0.007	0.49$	39.570	3.48*
Mn/P	0.161	0.063	0.004	39.130	0.196	0.067	0.004	33.980	1.120
Mn/K	0.019	0.008	0.001	42.110	0.018	0.008	0.001	44.940	1.010
Mn/Ca	0.069	0.026	0.001	37.680	0.083	0.025	0.007	30.680	1.030
Mn/Mg	0.126	0.066	0.004	50.000	0.141	0.055	0.003	39.040	1.310
Mn/S	0.308	0.108	0.012	35.640	0.213	0.712	0.005	33.400	2.31*
Mn/Cl	0.033	0.015	0.001	45.450	0.039	0.016	0.001	44.710	1.150
Mn/Fe	0.678	0.292	0.086	43.070	0.851	0.306	0.094	36.010	1.100
Mn/Zn	8.640	3.750	14.040	43.400	11.765	4.429	19.615	37.650	1.400

S D : Standard deviation
C V : Coefficient of variation
$: $\times 10^{-4}$
* : Significant at 5% level

Anexure 10

Relevant data for DRIS norms for coconut palms growing on laterite soil at Mannuthy

Form of expression	Low yield group (A)				High yield group (B)				Variance ratio (SA/SB)
	Mean	S D	Variance (SA)	C V (%)	Mean	S D	Variance (SB)	C V (%)	
N	1.350	0.360	0.129	21.740	1.480	0.290	0.082	19.590	1.580
P	0.143	0.028	0.001	19.580	0.174	0.048	0.003	27.590	2.380
K	1.610	0.350	0.123	21.730	1.230	0.181	0.033	14.720	3.74*
Ca	0.247	0.076	0.006	30.770	0.270	0.065	0.004	24.070	1.390
Mg	0.184	0.032	0.001	17.390	0.189	0.026	0.001	13.760	1.490
S	0.140	0.043	0.002	30.710	0.131	0.045	0.002	34.350	1.060
Cl	0.642	0.142	0.020	22.120	0.653	0.091	0.008	13.940	2.450
Fe	0.041	0.006	0.40$	15.560	0.043	0.005	0.30$	12.440	1.410
Zn	0.002	0.001	0.07$	35.000	0.002	0.001	0.04$	23.810	1.950
Mn	0.015	0.006	0.36$	40.000	0.022	0.010	1.00$	44.100	3.04*
N/P	9.820	3.150	9.930	32.080	9.390	3.870	14.980	41.220	1.510
N/K	0.870	0.280	0.077	32.180	1.240	0.341	0.116	27.410	1.510
N/Ca	5.880	1.990	3.970	33.840	5.830	1.840	3.390	31.600	1.170
N/Mg	7.410	1.780	3.190	24.020	7.950	1.710	2.930	21.540	1.090
N/S	10.460	4.020	16.160	38.430	12.330	3.770	14.190	30.550	1.140
N/Cl	2.210	0.830	0.695	37.560	2.330	0.662	0.439	28.360	1.590
N/Fe	33.560	8.320	69.160	24.790	34.700	7.650	58.530	22.050	1.180
N/Zn	748.150	279.880	78334.000	37.410	756.140	234.600	55052.000	31.030	1.420
N/Mn	101.460	32.730	1071.500	32.250	79.390	36.470	1329.700	45.930	1.240
P/N	0.114	0.045	0.002	39.470	0.122	0.042	0.002	34.430	1.160
P/K	0.096	0.041	0.002	42.710	0.146	0.046	0.002	31.710	1.260
P/Ca	0.618	0.199	0.039	32.200	0.671	0.204	0.042	30.360	1.040
P/Mg	0.789	0.176	0.031	22.310	0.938	0.279	0.078	29.730	2.500
P/S	1.070	0.237	0.056	22.150	1.480	0.658	0.433	44.430	7.69*
P/Cl	0.240	0.095	0.009	39.580	0.274	0.090	0.008	32.850	1.110
P/Fe	3.570	0.690	0.474	19.320	4.020	1.060	1.120	26.300	2.360
P/Zn	77.160	22.100	488.600	28.640	86.800	26.400	698.300	30.440	1.430
P/Mn	10.590	3.070	9.420	28.990	9.030	3.760	14.170	41.690	1.500
K/N	1.260	0.392	0.153	22.150	0.862	0.223	0.052	26.420	2.96*
K/P	12.070	4.870	23.750	40.350	7.910	3.850	14.790	48.610	1.610
K/Ca	7.270	2.980	8.880	31.110	4.870	1.670	2.790	34.310	3.18*
K/Mg	9.180	3.210	10.300	40.990	6.600	1.410	1.970	21.280	5.22*
K/S	13.290	7.150	51.180	34.970	10.530	4.260	18.150	40.450	2.82*
K/Cl	2.550	0.460	0.210	53.700	1.890	0.290	0.082	15.110	2.59*
K/Fe	41.130	12.630	159.520	18.040	29.000	8.450	71.460	29.150	2.230
K/Zn	903.600	369.600	136592.000	40.900	628.900	209.100	43718.000	33.250	3.12*
K/Mn	125.800	50.030	2503.200	39.770	69.170	39.340	1548.100	56.800	1.620

contd...

Form of expression	Low yield group (A)				High yield group (B)				Variance ratio (SA/SB)
	Mean	S D	Variance (SA)	C V (%)	Mean	S D	Variance (SB)	C V (%)	
Ca/N	0.196	0.089	0.008	45.410	0.190	0.065	0.004	34.420	1.840
Ca/P	1.750	0.450	0.203	25.710	1.710	0.840	0.700	48.930	3.45*
Ca/K	0.167	0.086	0.007	51.500	0.228	0.072	0.005	31.750	1.390
Ca/Mg	1.320	0.250	0.063	18.940	1.420	0.260	0.067	18.240	1.080
Ca/S	1.910	0.730	0.530	38.220	2.360	1.100	1.210	46.640	2.260
Ca/Cl	0.412	0.189	0.036	45.870	0.424	0.129	0.017	30.330	2.160
Ca/Fe	6.230	2.040	4.150	32.740	6.400	2.070	4.270	32.300	1.030
Ca/Zn	131.880	47.450	2251.300	36.000	135.700	41.300	1703.200	30.410	1.320
Ca/Mn	17.650	4.390	19.300	24.870	13.750	4.830	23.350	35.150	1.210
Mg/N	0.145	0.049	0.002	33.790	0.132	0.032	0.001	24.090	2.330
Mg/P	1.330	0.296	0.088	22.260	1.210	0.556	0.309	45.800	3.53*
Mg/K	0.123	0.051	0.003	41.460	0.158	0.035	0.001	21.960	2.160
Mg/Ca	0.782	0.150	0.023	19.180	0.726	0.134	0.018	18.390	1.260
Mg/S	1.430	0.468	0.219	32.730	1.630	0.628	0.395	38.610	1.800
Mg/Cl	0.306	0.107	0.114	34.970	0.294	0.050	0.003	17.040	4.55*
Mg/Fe	4.660	1.080	1.160	23.180	4.480	1.150	1.320	25.600	1.130
Mg/Zn	100.840	31.550	995.400	31.290	96.030	24.660	608.300	25.680	1.640
Mg/Mn	13.660	3.360	11.280	24.600	9.990	4.120	16.940	41.180	1.500
S/N	0.109	0.044	0.002	40.370	0.089	0.030	0.001	34.160	2.090
S/P	0.971	0.190	0.036	19.570	0.822	0.383	0.147	46.620	4.09*
S/K	0.095	0.045	0.002	47.370	0.109	0.042	0.002	38.070	1.190
S/Ca	0.618	0.294	0.087	47.570	0.522	0.234	0.055	44.790	1.580
S/Mg	0.775	0.272	0.074	35.100	0.707	0.261	0.068	36.950	1.080
S/Cl	0.239	0.116	0.013	48.540	0.205	0.076	0.006	37.220	2.310
S/Fe	3.430	0.797	0.635	23.240	3.010	0.910	0.832	30.270	1.310
S/Zn	75.820	29.200	852.880	38.510	66.430	26.600	707.680	40.040	1.210
S/Mn	10.390	4.200	17.650	40.420	7.030	3.870	14.980	55.060	1.180
Cl/N	0.510	0.183	0.033	35.880	0.460	0.119	0.014	25.990	2.340
Cl/P	4.800	1.870	3.510	38.960	4.200	1.950	3.810	46.500	1.080
Cl/K	0.404	0.070	0.005	17.330	0.539	0.077	0.006	14.240	1.200
Cl/Ca	2.870	1.120	1.250	39.020	2.560	0.720	0.510	27.910	2.44*
Cl/Mg	3.630	1.190	1.420	32.780	3.490	0.560	0.310	15.990	4.57*
Cl/S	5.260	2.590	6.710	49.240	5.610	2.250	5.080	43.950	1.320
Cl/Fe	16.340	4.910	24.090	30.050	15.450	4.350	18.950	28.180	1.280
Cl/Zn	351.600	124.500	15489.700	35.410	331.600	92.500	8563.300	27.900	1.810
Cl/Mn	49.730	19.960	398.300	40.140	35.900	18.000	324.000	50.140	1.230

contd...

Form of expression	Low yield group (A)				High yield group (B)				Variance ratio (SA/SB)
	Mean	S D	Variance (SA)	C V (%)	Mean	S D	Variance (SB)	C V (%)	
Fe/N	0.032	0.008	0.001	25.000	0.030	0.007	0.001	22.520	1.390
Fe/P	0.290	0.057	0.003	19.660	0.269	0.086	0.008	32.310	2.310
Fe/K	0.027	0.009	0.001	31.480	0.036	0.007	0.001	18.610	1.590
Fe/Ca	0.178	0.062	0.004	34.830	0.170	0.047	0.002	28.120	1.650
Fe/Mg	0.225	0.052	0.003	23.110	0.234	0.046	0.002	19.570	1.270
Fe/S	0.308	0.077	0.006	25.000	0.364	0.117	0.014	32.090	2.280
Fe/Cl	0.066	0.019	0.001	28.790	0.068	0.013	0.001	19.850	2.140
Fe/Zn	21.980	5.560	30.960	25.300	21.930	5.280	27.850	24.070	1.110
Fe/Mn	3.030	0.894	0.800	29.500	2.340	1.070	1.140	45.560	1.420
Zn/N	0.002	0.001	0.01$	56.250	0.002	0.001	0.01$	33.330	3.36*
Zn/P	0.014	0.005	0.05$	32.140	0.013	0.005	0.04$	41.860	1.410
Zn/K	0.001	0.001	0.04$	46.150	0.002	0.001	0.04$	29.410	1.230
Zn/Ca	0.008	0.003	0.07$	30.950	0.008	0.002	0.05$	28.750	1.280
Zn/Mg	0.011	0.004	0.05$	33.640	0.011	0.003	0.04$	27.270	1.510
Zn/S	0.015	0.007	0.06$	46.000	0.018	0.008	0.05$	43.260	1.240
Zn/Cl	0.003	0.001	0.04$	34.380	0.003	0.001	0.03$	28.130	1.330
Zn/Fe	0.049	0.020	0.001	40.410	0.049	0.013	0.001	27.420	2.220
Zn/Mn	0.147	0.062	0.004	42.180	0.109	0.049	0.002	44.770	1.630
Mn/N	0.012	0.006	0.001	51.670	0.016	0.007	0.001	46.450	1.330
Mn/P	0.102	0.028	0.001	27.450	0.014	0.097	0.009	68.900	12.15*
Mn/K	0.010	0.006	0.36$	59.600	0.019	0.010	1.00$	53.090	3.05*
Mn/Ca	0.060	0.013	1.69$	59.600	0.083	0.033	0.001	39.400	6.31*
Mn/Mg	0.079	0.025	0.001	31.650	0.117	0.046	0.002	39.320	3.45*
Mn/S	0.109	0.037	0.002	21.670	0.189	0.099	0.010	52.590	6.99*
Mn/Cl	0.024	0.012	0.001	33.940	0.036	0.017	0.001	49.010	1.980
Mn/Fe	0.359	0.113	0.013	31.500	0.528	0.254	0.065	48.160	5.11*
Mn/Zn	7.690	2.460	6.070	31.990	11.090	4.970	24.670	44.750	4.06*

SD : Standard deviation

CV : Coefficient of variation

$: $\times 10^{-4}$

* : Significant at 5% level

A B S T R A C T

A study on the applicability of diagnosis and recommendation integrated system (DRIS) in coconut palm (*Cocos nucifera* L.) was conducted at the department of Agronomy, college of Horticulture, Vellanikkara during 1991-'94. The study was conducted using coconut population of var. West Coast Tall being maintained at three research stations of Kerala Agricultural University namely, Regional Agricultural Research Station, Pilicode; Agricultural Research Station, Mannuthy and Coconut Research Station, Balaramapuram.

Eight hundred palms varying in their yield from 5.8 to 162.7 nuts per palm per year were selected for developing DRIS norms. Leaf samples were collected from the 14th frond and were analysed for macro and micronutrients namely N, P, K, Ca, Mg, S, Cl, Fe, Zn and Mn employing titrimetric, spectrophotometric, flame photometric or atomic absorption spectrophotometric method depending on the element. DRIS norms were developed using the data generated from the chemical analysis of leaf samples using the methodology of Beaufils (1973). The palm population was divided into low- and high-yielding subpopulations. The means and variances of nutrient concentration as well as their ratios (totalling 90 including inverse ratios) were worked out for the two

subpopulations. The variance ratios were then computed for each nutrient and each nutrient ratio to examine their statistical significance and those discriminating significantly between the two subpopulations were considered for DRIS norms. When both the ratio and its inverse form were significant, the one which had a higher variance ratio was selected. Mean values of the selected individual nutrients and nutrient ratios of the high-yielding subpopulation formed the DRIS norms.

Five nutrients and 33 nutrient ratios were selected on the basis of higher variance ratios as DRIS norms. Thirty one DRIS charts involving selected three-nutrient combinations can be constructed from the selected nutrient ratios. A qualitative assessment of nutritional imbalance involving three nutrients is possible by utilising these DRIS charts.

DRIS technique also provides another approach that can accommodate any number of nutrient ratios in which nutrient indices are worked out using DRIS norms and the observed nutrient ratios for the plant under test. The DRIS index for a nutrient indicates its relative abundance among the nutrients considered in its computation. Lower the value of the index for a nutrient, greater is its requirement.

The accuracy of diagnosis of nutritional imbalance by DRIS approach was tested for ten selected nutrients in palms receiving varying levels of NPK under a factorial experiment. From this it was observed that DRIS index for a nutrient varied not only with the applied level of that nutrient but also with the applied level of other nutrients and an improvement in yield with increase in DRIS index value was obtained for the application of K. The overall nutritional balance of a palm is given by the nutrient imbalance index (NII) which is the sum of the nutrient indices irrespective of the sign. A strong negative relationship was observed between this NII and yield.

DRIS norms developed on the basis of different yield cut-off values showed that they were affected by the criterion used for dividing the population into low- and high-yielding groups. Similarly DRIS norms developed for different soil types as well as for different climatic situations under the same soil type had also shown variations indicating their influence on DRIS. A comparison of DRIS approach with critical level approach indicated that DRIS could supplement information on balance or imbalance of nutrients in coconut palm and it could be used beneficially in nutrient management programmes in conjunction with critical level approach.